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THE INSTITUTION OF PRODUCTION ENGINEERS

JOURNAL

(October, 1947, Vol. XXVI, No. 10.)

Contents:

"MANUFACTURE AND APPLICATION OF SINTERED CARBIDES"
By E. TRENT, M.Met., Ph.D. and H. ECKERSLEY, A.M.I.Mech.E., M.I.P.E.

ANNUAL REPORT & ACCOUNTS, 1946/47

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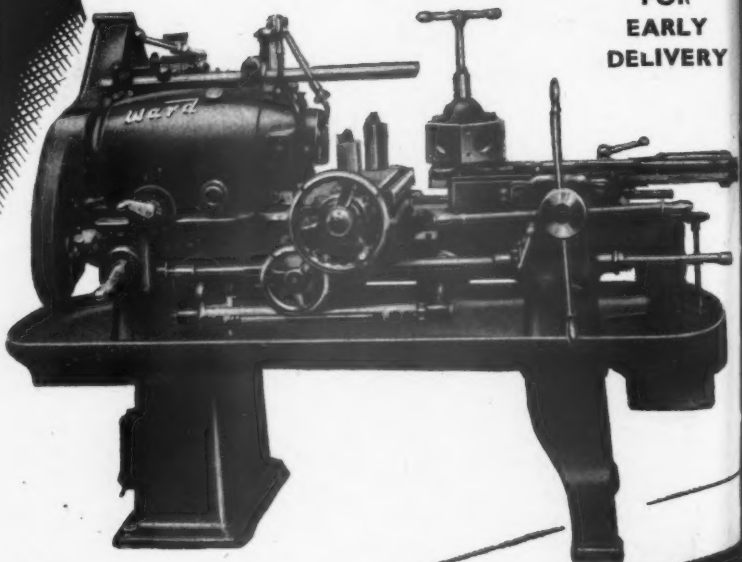

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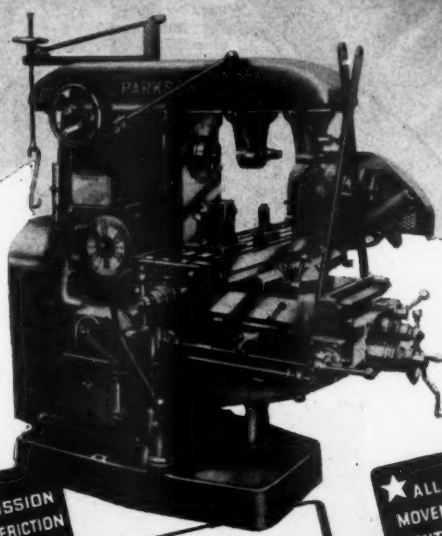

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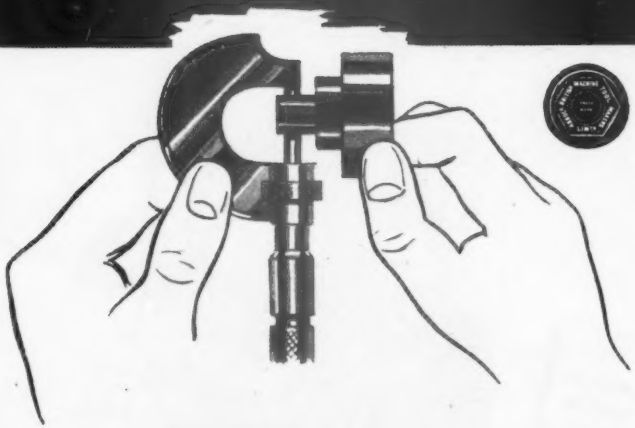

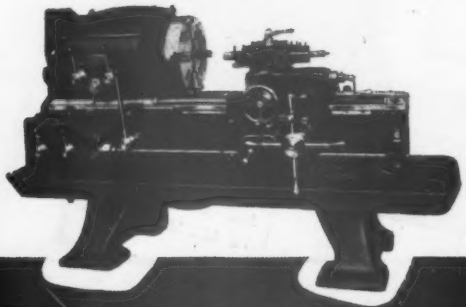

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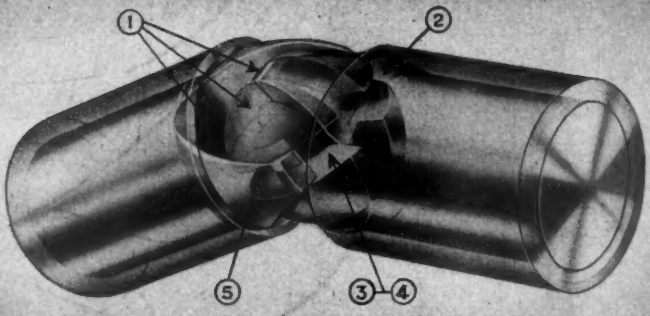

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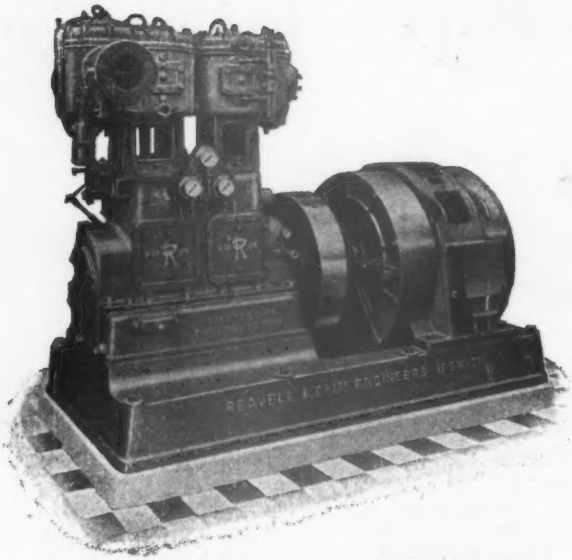

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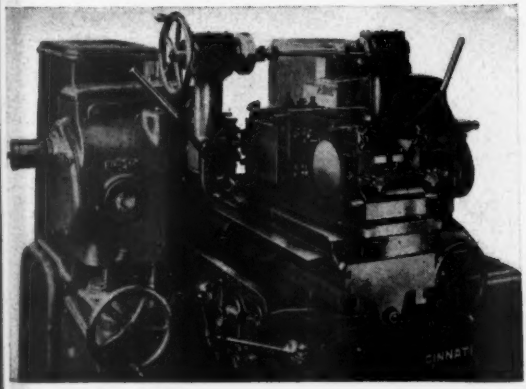

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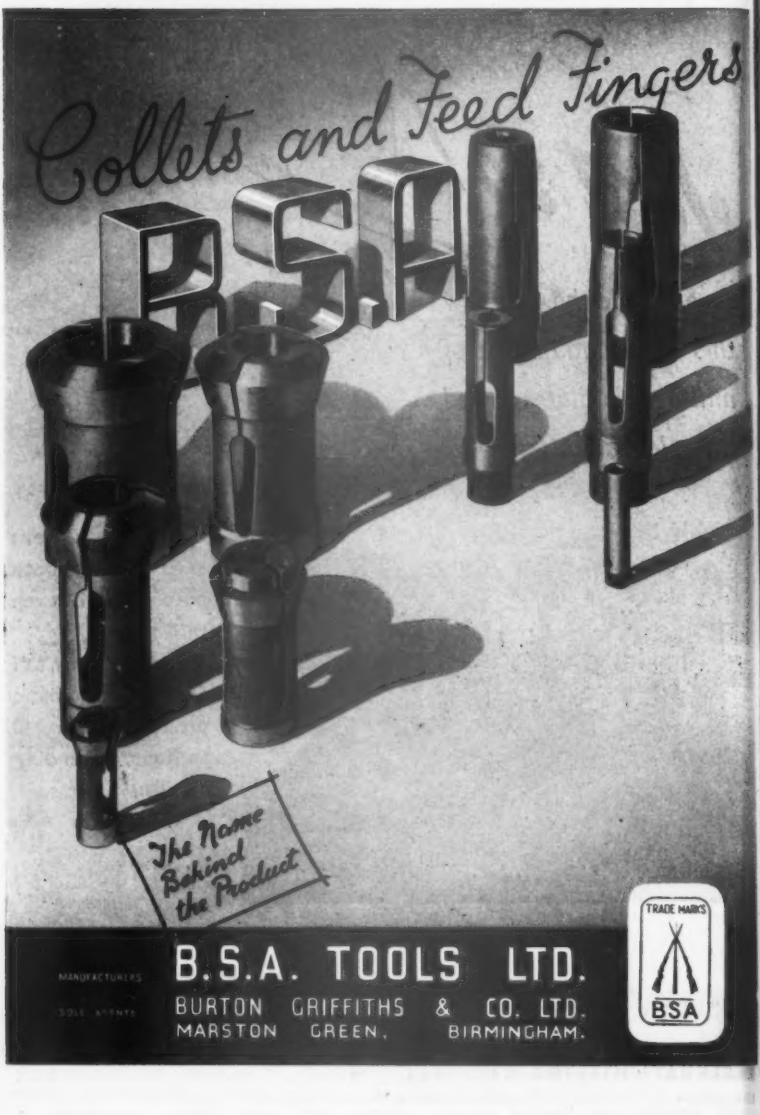
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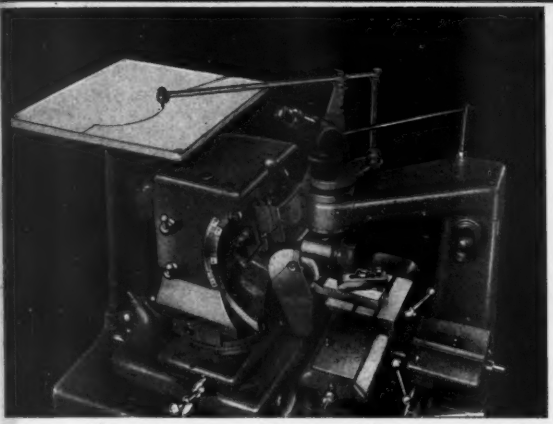

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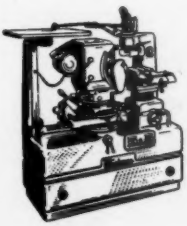

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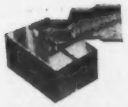

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INSTITUTION NOTES

October, 1947

Annual General Meeting.

Notice is hereby given that the Annual General Meeting of the Institution will be held on Thursday, 30th October, 1947, at the Institution of Civil Engineers, Great George Street, London, S.W.1, at 3-30 p.m.

AGENDA

1. Notice convening Meeting.
2. Minutes of previous Annual General Meeting.
3. Report on Election of Members of Council.
4. Presidential Address.
5. Annual Report of the Council.
6. Presentation of Statement of Income and Expenditure and Balance Sheet, and Auditors' Report.
7. Election of Auditors, 1947/48.
8. Election of Solicitors, 1947/48.
9. Votes of thanks.

By Order of the Council,
C. B. THORNE,
Director and General Secretary.

Council Meeting

The next meeting of Council will be held at the Institution of Civil Engineers, Great George Street, London, S.W.1., on Thursday, 30th October, 1947, at 11.00 a.m.

Section Meetings.

The following meetings have been arranged to take place in October and November. Where full details are not given, these have not been received at the time of going to press.

October Meetings.

1st Manchester Section. A visit to the Lancashire Steel Corporation, Irlam, has been arranged.

1st Nottingham Section. A lecture on "Product Styling" will be given at the Victoria Hotel, Milton Street, Nottingham, at 7-00 p.m.

October Meetings—*Cont.*

6th Yorkshire Section. A lecture on "Noise and Vibration in Machinery" will be given by W. A. Tuplin, D.Sc., at the Hotel Metropole, Leeds, at 7-00 p.m.

8th Sheffield Section. An address will be given by Col. F. A. Neill.

8th Preston Section. A lecture on "British Management at the Crossroads" will be given by Mr. Lewis C. Ord at Messrs. Clayton, Goodfellow & Co., Ltd., Blackburn, at 7-15 p.m.

8th Southern Section. A visit to the Southampton Corporation Power Station has been arranged.

10th Coventry Section. A lecture on "The American Attitude to Production Modernisation," will be given by Mr. H. H. Beeny in Room A5, Coventry Technical College, Coventry.

10th North-Eastern Graduate Section. A lecture on "Crushing Wheels for Form Grinding" will be given by Mr. G. H. Ashbridge.

13th Luton Section. A talk on American production activities will be given by Mr. E. W. Hancock, M.B.E., M.I.P.E., at the Town Hall, Luton, at 7-00 p.m.

13th Halifax Section. A lecture on "The Manufacture of Seamless Steel Tubes" will be given by Dr. Jenkins, at Whiteleys' Café, Westgate, Huddersfield, at 7-00 p.m.

14th Birmingham Graduate Section. A lecture on "Foundrywork and Production" will be given by Mr. Biddle, at the James Watt Memorial Institute, Birmingham, at 7-15 p.m.

14th Wolverhampton Graduate Section. A lecture on "Air Operated Fixtures" will be given by Mr. N. Watts, at Walsall.

14th Yorkshire Graduate Section. A visit to Messrs. Crofts (Engineers) Ltd., Bradford, has been arranged, starting at 7-00 p.m.

15th Birmingham Section. A lecture on "Payment by Results Critically Examined," will be given by Mr. E. C. Gordon England, F.R.Ae.S., F.I.I.A., F.I.M.I., M.I.P.E., at the James Watt Memorial Institute, Birmingham, at 7-00 p.m.

15th Wolverhampton Section. A lecture on "Motion Study and Operation Analysis," illustrated by a film, will be given by Miss A. G. Shaw, M.A., M.I.P.E., at the Wolverhampton and Staffordshire Technical College, at 7-00 p.m.

October Meetings—*Cont.*

15th Birmingham Graduate Section. An afternoon visit to the G.E.C. Foundry at Whitton has been arranged.

15th Western Section. A lecture on "The Cost Accountant and His Place in Industry" will be given by Mr. H. A. Simpson, at the Grand Hotel, Bristol, at 6-45 p.m.

15th Liverpool Sub-Section. A lecture on "Die Casting of Light Alloys" will be given by Mr. H. W. Fairbairn, A.M.I.P.E., at Liverpool University, at 7-15 p.m.

16th Glasgow Section. A lecture on "Colour Schemes for Factories and Machines" will be given by Mr. S. A. Wood at the Institution of Engineers and Shipbuilders in Scotland, Glasgow, at 7-30 p.m.

17th Eastern Counties Section. A lecture on "An Outline of Modern Die Forging Practice" will be given by Mr. H. M. H. Fox, M.I.P.E., at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

20th Derby Sub-Section. A lecture on "Commercial Possibilities of the Lost Wax Process" will be given by Mr. A. Short, Grad.I.P.E.

21st Coventry Graduate Section. A Discussion Meeting on "The Training of the Production Engineer" has been arranged.

21st Wolverhampton Graduate Section. A visit to the Fischer Bearings Co., Ltd., has been arranged.

22nd Manchester Section. A lecture on "The Mechanism of Sheet Metal Drawing" will be given by Professor H. W. Swift, M.A., B.Sc.(Eng.), M.I.Mech.E.

23rd Shrewsbury Sub-Section. A lecture on "Drop Stamping" will be given by Mr. G. Wilson.

25th Glasgow Section. A Luncheon will be held at The Grosvenor, Gordon Street, Glasgow, at 1-00 p.m.

27th Halifax Graduate Section. A lecture entitled "Making a Typewriter" will be given by Mr. R. M. Evans, at the Technical College, Halifax, at 7-00 p.m.

November Meetings

1st Birmingham Section. A Dance will be held at the Grand Hotel, Birmingham.

November Meetings—*Cont.*

3rd Yorkshire Section. A lecture on "Engineering Uses of Cast Iron" will be given by Dr. H. T. Angus, M.Sc., at the Midland Hotel, Bradford, at 7-00 p.m.

4th Coventry Graduate Section. A lecture on "The Production of Aluminium Houses" has been arranged.

5th Preston Section. A lecture on "Fabrication versus Castings" will be given by Mr. R. M. Watts, A.M.I.W., at the Harris Institute, Corporation Street, Preston, at 7-15 p.m.

5th Nottingham Section. A lecture on "Tooling and Methods Planning" will be given at the Victoria Station Hotel, Milton Street, Nottingham, at 7-00 p.m.

6th Glasgow Section. An Informal Discussion will be held at the Institution of Engineers and Shipbuilders in Scotland, Glasgow, at 8-00 p.m.

7th Preston Section. The Annual Dinner Dance will be held at the Victoria and Station Hotel, Preston.

7th North-Eastern Graduate Section. A lecture on "The Manufacture of Gauges" will be given by Mr. N. Herbert, Grad.I.P.E.

10th Halifax Section. A lecture on "Full Employment in Industry" will be given by Mr. Austin Hopkinson at the White Swan Hotel, Halifax, at 7-00 p.m.

11th Birmingham Graduate Section. A lecture on "Production Metal Finishing" will be given by Mr. H. Silman at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-15 p.m.

12th Wolverhampton Section. A lecture on "Cutting Lubricants and Coolants," will be given by Mr. H. H. Beeny, M.Met., F.I.M., at the County Technical College, Wednesbury, at 7-00 p.m.

12th Sheffield Section. A lecture on "Foremen and Their Duties" will be given by Mr. E. Mensforth, M.I.P.E.

12th Birmingham Graduate Section. A visit to Fort Dunlop, Erdington, has been arranged.

12th Southern Section. A lecture on "Goblin and Ghost Jet Propulsion Engines" will be given by Mr. J. L. Edwards at the University College, Southampton, at 7-30 p.m.

November Meetings—*Cont.*

12th Manchester Graduate Section. A lecture on "High Grade Cast Iron Castings" will be given by Mr. E. Longden, M.I.Mech.E., at the College of Technology, Sackville Street, Manchester, at 7-15 p.m.

13th London Graduate Section. A lecture on "Electric Resistance Welding" has been arranged.

14th Coventry Section. A lecture entitled "Some Notes on the Design and Use of Inspection Gauges" will be given by Mr. L. H. Leedham, M.I.P.E., A.M.I.Mech.E., in Room A5 Coventry Technical College, Coventry.

15th Yorkshire Graduate Section. A visit to Messrs. Scott Motors (Saltaire), Ltd., Shipley, has been arranged, starting at 2-30 p.m.

17th Luton and District Section. A lecture on "Interchangeability in Manufacture" will be given by Mr. F. Baker at the Town Hall, Luton, at 7-00 p.m.

17th Derby Sub-Section. A lecture on "Development in Gear Cutting" will be given by Mr. F. J. Everest, M.Sc., A.M.I.Mech.E., A.M.I.E.E., at the Art School, Green Lane, Derby, at 6-45 p.m.

18th Wolverhampton Graduate Section. A lecture on "The Manufacture of Small Tools" has been arranged.

19th Birmingham Section. A lecture on "Electronics in Industry" will be given by Dr. W. Wilson, at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m.

19th Western Section. A lecture on "Incentives to Direct and Indirect Engineering Workers" will be given by Mr. K. E. Taylor, A.M.I.P.E., at the Grand Hotel, Bristol, at 6-45 p.m.

19th Liverpool Sub-Section. A lecture on "Car Production" will be given by Mr. L. P. Coombes, M.I.P.E., at Liverpool University, at 7-15 p.m.

20th Halifax Section. The Annual Dinner Dance will be held at The George Hotel, Huddersfield, from 7-00 until midnight.

20th Glasgow Section. A lecture on "Production Engineering in Marine Shops" will be given by Mr. J. Green at the Institution of Engineers and Shipbuilders in Scotland, Glasgow, at 7-30 p.m.

November Meetings—*cont.*

21st Eastern Counties. Mr. J. B. Webster, M.I.P.E., will give his Presidential Address in the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

25th Halifax Graduate Section. A lecture on "Press Tools" will be given at the Technical College, Huddersfield, at 7-00 p.m.

26th Manchester Section. A lecture on "Electronics in the Service of the Engineer" will be given by Mr. S. A. Ghalib.

29th Yorkshire Graduate Section. A lecture on "Plastics in Engineering" will be given at the Great Northern Hotel, Leeds, at 2-30 p.m.

Personal.

Mr. H. M. Brack, M.I.P.E., has been appointed Works Manager of Messrs. Linotype Machinery, Ltd., Altrincham, Cheshire.

Mr. T. S. Harker, B.Sc., A.M.I.Mech.E., M.I.Mar.E., A.M.I.P.E., Principal of the Ipswich School of Technology since 1941, has been appointed Principal of the Wimbledon Technical College. Mr. Harker has served on the Committee of the Eastern Counties Section since 1942.

Mr. A. N. Bubb, A.M.I.P.E., has taken a position with The Anglo-Iranian Oil Co., Ltd., in London.

Mr. Ralph Parish, Int.A.M.I.P.E., is now General Manager of the Overseas Engineering Company, Sekondi, West Africa.

Mr. G. J. Willmott, Grad.I.P.E., has taken up a position with Technical Industrial Specialists, London.

Mr. Robert B. Williams, Grad.I.P.E., is in charge of the Plant and Maintenance Drawing Office in the Works Engineers' Dept. of the Tube Investments Group.

Mr. N. Stait, Grad.I.P.E., has been appointed Production Manager of a new factory opened at Oulton by the Electrical Apparatus Co., Ltd.

Mr. J. Renouprez, Grad.I.P.E., is now Assistant Works Manager of J. Mountford & Co., Ltd., Manchester, subsidiary firm of J. Holroyd & Co., Ltd., of Rochdale.

Mr. P. S. McCaig, Grad.I.P.E., has joined the staff of Messrs. Swire and Maclaine, Ltd., Hong Kong, as Technical Representative.

London Graduate Section Visit

On Tuesday, 29th July, by courtesy of Messrs. Hoover, Ltd., the London Graduate Section was able to visit and inspect the Company's Perivale Works. The members who attended were received by Mr. B. H. Dyson, M.I.P.E., who after giving a brief outline of the work of the Company, emphasised the importance which Graduate and Student Members should attach to their association with the Institution. He felt that this visit—the first of a series—would assist Graduate Members in getting together to create an active and useful Section.

After a tour of the factory, which embraced the main Machine Shops, Moulding, Die-Casting and Fettling Departments, the Tool-room, the Metal Finishing Department, final assembly lines and inspection bays, and terminating in the Packaging and Despatch Department, the members were the guests of the Company for tea, when they were joined by Mr. Dyson and Major C. B. Thorne, M.C., Director and General Secretary of the Institution.

After tea, an interesting discussion developed, and the proceedings were concluded with the proposal of a vote of thanks by Mr. H. G. Shakeshaft to Messrs. Hoover, Ltd.

Obituary

We deeply regret to announce the deaths of two prominent Members of the Institution, Mr. H. A. Drane, M.I.P.E., and Mr. E. J. Piggott, M.I.P.E.

Mr. Drane, who died following a serious operation, was Service Manager of Messrs. Alfred Herbert, Ltd., with which firm he had spent the whole of his career. He was for some time Chief Technical Assistant to the late Mr. Oscar Harmer.

He was President of the Coventry Section during 1935/36, and at the time of his death had been an elected member of Council for many years. He was also a valued member of the Membership and Education Committees. Those who knew Mr. Drane will wish to associate themselves with the following appreciation, written by a close friend and colleague :

"By the death of Harry Drane we lose a Member of Council who has served our Institution for many years, both as an active member of the Coventry Section, and also on Council and on various Committees. A man of strong opinions and well able to speak his mind, he was ever a champion of straightforward dealing and jealous where the reputation and good name of the Institution were concerned.

"He gave a good deal of his time in helping to spread the knowledge of engineering technique wherever possible, and gave

many lectures to Engineering Societies and Technical Institutions throughout the country. Harry Drane took a great interest in the rising generation and was always willing to help and to arrange visits for students and graduates to the works of Alfred Herbert, Ltd., Coventry, with whom he was connected throughout his working life, having joined their staff in 1905."

Mr. Piggott was an active member of Luton Section for nearly 15 years. He was Section President from 1944/46, and at the time of his death had served on the Section Committee for eight years. He had been with Messrs. Vauxhall Motors, Ltd., for over 30 years in charge of Machine Maintenance and Development.

Both Mr. Piggott and Mr. Drane were men of outstanding ability and integrity, and their loss will be keenly felt and sincerely mourned.

The Roorkee University (Thomason College of Engineering), India

The Institution has been honoured by an invitation extended to the President, Mr. N. Rowbotham, C.B.E., to attend the Centenary Celebrations of the Thomason College of Engineering, Roorkee, India, on December 15/16th, 1947. During the celebrations a formal announcement will be made that the College will in future be known as Roorkee University, for technical education, and the Vice-Chancellor will be formally installed in office and the Charter of the University will be presented at the same time.

As he is unable to visit India, the President will be represented on this memorable occasion by Mr. J. D. Scaife, M.I.P.E., a Founder-Member of the Institution, and President during 1923/24.

A brief biography of Mr. Scaife will be found on page 11 of these Notes.

Luton and District Graduate Section

The Luton and District Graduate Section, in their search for a progressive programme for their coming season, have produced a "Programme with a Plan."

Realising that the young production engineer is the key to the nation's recovery, their meetings this season have been designed around a central theme of "Efficient Production and the Young Engineer." The subjects to be dealt with by competent speakers are :

Design for Production.
Planning for Production.
Tooling for Efficient Production.
Production Control.
Production Engineering Research and Industry.

These will be interspersed with suitable visits and demonstrations.

It is hoped that Students and Graduates will recognise the unique possibilities of this programme, and as the engineer of tomorrow, take full advantage of the scope it offers.

Junior Membership.

Students and Graduates of the Institution are reminded that :—

(*a*) Students must qualify for transfer to a higher grade of membership by the time they attain the age of twenty-eight years.

(*b*) Graduates may apply for transfer to a higher grade of membership on attaining the age of twenty-eight years, and in any case must apply for transfer by the time they have reached the age of thirty-two years.

Forms of application for transfer may be obtained from Head Office.

Food Parcels From Australia.

In his Address to Council on 10th July, 1947, Mr. F. Glover, M.I.P.E., Vice-President of the Australian Sub-Council, mentioned that he had been asked by a firm in Australia to nominate a similar firm in this country, in order that food parcels might be sent to employees.

Mr. Glover informs us that the engineering concern he has recommended is The Coventry Engineering Co., Ltd., of Coventry. The Australian firm which has generously undertaken to supply these parcels is that of Messrs. W. A. Deutsher Pty., Ltd., of Melbourne, whose Works Manager is Mr. R. W. Deutsher, winner of the Lord Austin Prize for 1946.

The following letter from Mr. C. L. Payne, Secretary to Messrs. W. A. Deutsher Pty., Ltd., to Mr. A. R. Grindlay, O.B.E., Manager of The Coventry Engineering Co., Ltd., in connection with the scheme, is evidence of the great goodwill and friendship which is felt in the Dominion towards the " Old Country."

" The Coventry Engineering Co., Ltd.,
Shackleton Road,
Coventry, England.
The Manager, Mr. Grindlay, O.B.E.

DEAR SIR,

We wish to acknowledge the receipt of a letter dated 24th ult. from Mr. F. Glover, M.I.P.E., nominating your Company to be the recipient of parcels of food to be sent by the Committee of the Food for Britain Appeal within our own factory. We accept with pleasure the recommendation by Mr. Glover,

Our staff and personnel are fully aware of the many difficulties you are all having in England at the present time, and such a thought had prompted us to form a committee for the above purpose.

This committee is now in full swing endeavouring to raise all the money possible, so that we may purchase parcels from time to time and despatch them to your employees, whom we have adopted to be the recipients of whatever parcels are available.

Might we suggest that you supply us by return airmail, the names, addresses, ages and the position held by every employee in your works, including the executive and management.

Our idea is this. For instance, the Storeman in our factory would, at some early date, despatch a parcel to the Storeman in your factory, and a similar method would apply from Accountant to Accountant, Works Manager to Works Manager, and so on.

We would like to assure you that every effort is being made to obtain sufficient money to send the maximum number of parcels away in the shortest possible time, and a guide from you as to the type and contents of parcels would be appreciated in your reply letter.

Another point we wish to add is that the Directors here have kindly decided as a gesture of goodwill to pay all postage costs on all parcels despatched to Britain and your Company, by the Committee of our Food for Britain appeal.

We know that your problems are tremendous and we feel that we have some idea of what is before you, but nevertheless we convey to you our respectful wishes that your difficulties will be overcome very quickly, so that you all may take advantage of and enjoy to the fullest some of the good things in life which cannot be taken advantage of during the present crisis. Please accept our very good wishes for the successful co-operation between us both in this matter of parcels for your employees.

Yours faithfully,

for W. A. Deutsher Pty., Ltd.,

C. L. PAYNE, *Secretary.*"

Honours.

It was stated in the August issue of the Journal that Mr. J. Cunningham, O.B.E., was General Manager of Messrs. Ruston & Hornsby, Ltd., Lincoln. This should, in fact, have read "General Manager of the Boiler Division of Messrs. Ruston & Hornsby, Ltd."

Mr. J. D. Scaife, M.I.P.E.

Mr. J. D. Scaife comes of a long line of master craftsmen who have been connected with the textile machinery industry for many generations. At an early age he was called upon to take charge of the family business of Robert Scaife, Ltd., Colne.

At the age of 23, he took up a managerial position in the sewing machine industry, which he held for some years, before entering the machine tool industry for the manufacture of lathes, drilling and shaping machinery.

Mr. J. D. Scaife.

Returning to his family business in 1910, as managing partner, Mr. Scaife developed the manufacture of gauges, and in 1916 the firm was one of the largest gauge manufacturers in the industry.

In 1916, he left the business in the care of his brothers, and spent some time in the aero-engine industry. In 1918, as the nominee of His Majesty's Government, he entered the ball and roller bearing industry and for ten years worked on the development of high quality anti-friction bearings.

During the past 17 years, Mr. Scaife has been engaged on the development of high production, high precision grinding, and fine boring and tooling machines, as well as planing machines.

It has always been his expressed conviction that accuracy and low operating costs are synonomous, and his experience has justified this conclusively.

Mr. Scaife was one of the pioneers of the Institution of Production Engineers in 1921, and read the first paper ever presented to a meeting. He was elected President for the year 1923/24, and has been a member of Council for many years. His untiring efforts have played a major part in bringing the Institution to its prominent position in the world of engineering.

For many years he has been interested in the industrial development of India. Upon his retirement from active business he went to India to act as Consultant to a group of Indian industrialists, to whom his vast knowledge and experience have been of tremendous value. He played a prominent part in the formation of the Calcutta Section of the Institution, which was inaugurated in February, 1947, and now has 31 members.

Issue of Journal to New Members

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Important

In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

THE INSTITUTION OF PRODUCTION ENGINEERS

BALANCE SHEET
and
Income and Expenditure Account for the Year ended 30th June, 1947.

36 PORTMAN SQUARE · LONDON · W.1

THE INSTITUTION OF ROD

BALANCE SHEET at 30

LIABILITIES

	£ s. d.	£ s.
The Viscount Nuffield Gift	24,428 19 8	
The Lord Austin Prize Fund	100 0 0	
The Hutchinson Memorial Fund	100 0 0	
		24,628 19
Leasehold Premises Sinking Fund	1,144 10 0	
Dilapidations Reserve Fund	600 0 0	
		1,744 10
Income and Expenditure Account :		
Balance at 1st July, 1946	13,073 15 9	
Add Excess of Income over Expenditure for the year	1,204 10 7	
		14,278 6
		40,651 16

CURRENT LIABILITIES

Sundry Creditors	740 4 10	
Subscriptions Received in Advance	198 7 2	
Structural Repairs Reserve Account (Incorporating Building and Development Fund)	2,820 0 0	
Furniture and Equipment Reserve Account	1,360 9 6	
Hazleton Memorial Library Account	715 5 6	
		5,834 7
		£46,486 3

Note.—Owing to the war, adjustments will be required at a future date in respect of certain assets included in the above account.

N. ROWBOTHAM, *President.*
HERBERT SCHOFIELD, *Chairman of Council and Finance Committee.*
C. B. THORNE, *Director-General and Secretary.*

INCOME and EXPENDITURE ACCOUNT the

EXPENDITURE

1946		£ s.	946
7,608	To Salaries	9,391 4	
571	„ Rent, Light, Heating and Cleaning	628 12	3,867
1,020	„ Section Expenses	1,220 6	486
2,309	„ Printing, Postage, Stationery and Telephone	2,874 6	
4,177	„ Cost of Journal and Bulletin	5,913 12	4,078
478	„ Travelling and Expenses of Meetings other than Section Meetings	803 10	417
191	„ Professional Charges and Insurance	176 15	—
118	„ Donations and Grants	112 6	—
204	„ Repairs and Renewals	274 4	—
6	„ Lord Austin Prize	—	
147	„ Miscellaneous	194 8	4,650
—	„ Transfer to Hutchinson Memorial Fund	60 0	255
127	„ „ „ Leasehold Premises Sinking Fund	127 3	
100	„ „ „ Dilapidations Reserve Fund	100 0	—
—	„ „ „ Structural Repairs Reserve Fund (36 Portman Square)	660 0	—
—	„ „ „ Furniture and Equipment Reserve Fund (36 Portman Square)	1,500 0	—
175	„ Amount written off Furniture, Fittings and Plant	174 19	
6	„ Loss on Sale of Investments	—	
6,463	„ Payments to Research Department	—	
		24,211 9	
1,053	„ Balance, being excess of income over Expenditure	1,204 10	
£24,753		£25,415 19	4753

ON PRODUCTION ENGINEERS

E SHEET at 30th June, 1947

FIXED ASSETS

£	s.		£	s.	d.	£	s.	d.
		USEHOLD PREMISES at cost				3,481	0	0
		(Depreciation is provided by a Sinking Fund)						
		NITURE, FITTINGS AND PLANT at cost, *less* amount written off :						
24,628	19	Balance at 1st July, 1946	1,242	4	6			
		Additions during year	244	6	4			
1,744	10		1,486	10	10			
		Less Amount written off	174	19	2			
						1,311	11	8
		ND INVESTMENTS at cost : As Scheduled (Market Value £26,933) ...				24,628	19	8
14,278	6	SING FUND POLICIES : As Scheduled				1,744	10	0
40,651	16					31,166	1	4

CURRENT ASSETS

		NDRY DEBTORS, DEPOSITS AND STOCKS	2,243	11	10			
		ODUCTION ENGINEERING RESEARCH ASSOCIATION OF GREAT BRITAIN—						
		Balance due on transfer of Assets	4,000	0	0			
		NERAL INVESTMENTS at cost : As Scheduled (Market Value £9,371) ...	9,002	10	0			
		SH :						
		At Bank 85 5 2						
5,834	7	At Post Office Savings Bank 1,136 9 0						
		In Hand 91 3 0						
		Less Overdraft (Current Account) 1,312 17 2 1,238 17 4						
			73	19	10			
						15,320	1	8
£46,486	3					£46,486	3	0

AUDITOR'S REPORT.—We have audited the above Balance Sheet dated 30th June, 1947, and we have tained all the information and explanations we have required. The Australian Section Accounts are included in the above Balance Sheet. Subject to the foregoing, in our opinion such Balance Sheet is perly drawn up so as to exhibit a true and correct view of the state of the Institution's affairs according the best of our information and the explanations given us, and as shown by the books of the Institution.

Kingsway House,
London, W.C.2.
6th *August*, 1947.

GIBSON, APPLEBY & Co.,
Auditors,
Chartered Accountants.

CCOUNT for the year ended 30th June, 1947

INCOME

£	s.	1946		£	s.	d.	£	s.	d.
9,391	4		By Subscriptions Received—						
628	12	3,867	Current	14,595	13	2			
1,220	6	486	Arrears	291	13	0			
2,874	6						14,887	6	2
5,913	12	1,078	,, Interest on Investments				1,162	16	8
803	10	4,417	,, Journal Receipts				4,853	6	7
176	15	—	,, Sale of Publications				66	17	10
112	6	—	,, Australian Sub-Council				796	16	1
274	4	—	,, South African Association of Production Engineers—						
—			(Donation)				100	0	0
194	1	1,650	,, Research Receipts				—		
60	0	255	,, War Damage Commission				—		
127	3		,, RESEARCH DEPARTMENT :						
100	0	—	Balance at 1st July, 1946	454	2	11			
660	0	—	Net Receipts	155	4	3			
1,500	0	—	Surplus on transfer of assets to Production Engineering						
174	19		Research Association of Great Britain	2,939	9	1			
—							3,548	16	3
—									
24,211	9								
1,204	10								
£25,415	19	14,753					£25,415	19	7

AUSTRALIA[illegible]B-COU

BALANCE SHEE[illegible]at 31s

LIABILITIES

	£A.'s £ s. d.	£ s. d.	£'s Sterling £ s. d.	£ s. d.
ACCUMULATED FUNDS :				
As at 31st March, 1946	1,347 2 2		1,077 13 9	
Add Excess of Receipts over Payments for the year	309 10 11	1,656 13 1	247 12 9	1,325 6
Less Transfers—				
London 28th October, 1946 ...	14 13 8		11 15 0	
London 11th February, 1947 ...	1,000 0 0	1,014 13 8	800 0 0	811 15
		£641 19 5		£513 11

S. D. McPHEE, *Chairman of Australian Sub-Council.*
JAMES M. STEER, *Hon. Treasurer.*

INCOME and EXPENDITURE ACCOUN[illegible] the [illegible]

EXPENDITURE

	£A.'s £ s. d.	£'s Sterling £ s.
To Postages, Cables, Telegrams and Sundries	48 11 10	38 17
,, Bank Charges	2 2 5	1 14
,, Printing and Stationery	90 2 1	72 1
,, Australian Journals and Reporting	83 17 8	67 2
,, Meeting Hall	28 19 8	23 3
,, Epidiascope	2 17 0	2 5
,, Depreciation on Furniture and Fittings	3 15 0	3 0
,, Richardson's Paper	2 18 4	2 6
,, Travelling Expenses, A.S.C.	8 19 0	7 3
,, Balance, being excess of receipts over payments	309 10 11	247 12
	£581 13 11	£465 7

...B-COUNCIL

...at 31st March, 1947

ASSETS

	£A.'s			£'s Sterling		
	£ s. d.	£ s. d.		£ s. d.	£ s. d.	
...H IN BANK—31st March, 1947 :						
Melbourne Section	36 6 9			29 1 5		
Sydney Section	88 11 5			70 3 6		
Sydney, A.S.C.	476 11 8			381 5 4		
		601 9 10			480 10 3	
...TY CASH :						
Melbourne Section	20 1 8					
Sydney Section O/D	17 1					
		19 4 7			16 1 3	
...NITURE AND FITTINGS	25 0 0			20 0 0		
Less Depreciation, 15%	3 15 0			3 0 0		
		21 5 0			17 0 0	
		£641 19 5			£513 11 6	

AUDITOR'S REPORT.—The foregoing is in accordance with the audited records of the Australian Section submitted to us and is a true and correct statement of the affairs of the Section prepared upon a receipts and payments basis according to the best of our knowledge and information.

WALKER & WALKER,
Chartered Accountants (Aust.).

...COUN... the year ended 31st March, 1947

INCOME

	£A.'s		£'s Sterling	
	£ s. d.		£ s. d.	
Subscriptions and Entrance Fees received	566 2 6		452 18 1	
Donations to Research Fund	12 6		10 0	
Sale of Publications	13 8 11		10 15 2	
Examination Fees	1 10 0		1 4 0	
	£581 13 11		£465 7 3	

INVESTMENTS, 30th JUNE, 1947

	£ s. d.	£ s. d.
SCHEDULE OF FUND INVESTMENTS.		
The Viscount Nuffield Gift :		
£7,124 19 10 3½% War Stock	7,428 19 8	
£8,389 9 6 3% National Defence Stock 1954/58	8,000 0 0	
£9,038 0 0 4% Canadian Pacific Railway Perpetual Consolidated Debenture Stock	9,000 0 0	
		24,428 19 8
The Lord Austin Prize Fund :		
£95 8 5 3½% War Stock		100 0 0
Hutchinson Memorial Fund :		
£95 8 5 3½% War Stock		100 0 0
		£24,628 19 8
SCHEDULE OF GENERAL INVESTMENTS (UNALLOCATED) :		
£1,000 0 0 3% Defence Bonds		1,000 0 0
£274 12 0 3½% War Stock		290 0 0
£644 15 2 Ayr County Council 3% Redeemable Stock, 1956 ...		650 0 0
£615 9 5 London County Consolidated 3% Stock, 1956/61 ...		620 0 0
£595 18 2 Plymouth Corporation 3% Redeemable Stock, 1956 ...		600 0 0
£148 3 11 3% War Stock, 1955/59		150 0 0
£382 13 8 3½% War Stock		400 0 0
£190 16 11 3½% War Stock		200 0 0
£37 7 3 3½% War Stock		40 0 0
£50 2 6 3½% War Stock		52 10 0
£5,000 0 0 3% Savings Bonds 1965/75		5,000 0 0
Total as per Balance Sheet		£9,002 10 0
SCHEDULE OF SINKING FUND POLICIES.		
Leasehold Premises Sinking Fund :		
Norwich Union Life Insurance Society Policy—Premium Paid ...		1,144 10 0
Dilapidations Reserve Fund :		
General Accident Fire & Life Assurance Corporation Ltd. Policy—Premiums Paid		600 0 0
		£1,744 10 0

ANNUAL REPORT 1946/47

Your Council has pleasure in presenting the following report for the year 1946/1947 :—

1. Growth of the Institution.

This has been an outstanding year for the Institution. It has not only increased in stature through the addition to its ranks of many prominent individuals, including Sir Charles Bartlett, Sir Lionel Kearns, C.B.E., Mr. F. H. Rolt, O.B.E., of the National Physical Laboratory, Mr. Robert Blackburn, O.B.E., and others of similar calibre, but its membership is steadily growing and has increased by 641 members during the year. Furthermore, the Institution can claim to have received an increasing measure of recognition from Government Departments and public bodies, and its activities have been widely reported in both the National and the Provincial Press.

2. National Productive Efficiency Conference, Wolverhampton.

The Wolverhampton Section arranged a most successful Conference which was held on 8th March at the Wolverhampton Technical College, and opened by His Worship the Mayor of Wolverhampton, Alderman C. B. V. Taylor. The introductory address was delivered by Sir Godfrey Ince, K.C.B., K.B.E., C.B., Permanent Secretary to the Ministry of Labour, who discussed Britain's Manpower Budget. The undermentioned papers were then presented, and were followed by discussions.

Manpower :

"Training for Efficient Production," by J. W. Berry, M.I.Mech.E., M.I.P.E.

"Utilisation of Manpower," by H. Briggs.

Management :

"The Approach to Management," by W. C. Puckey, M.I.P.E., F.I.I.A.

"Management—Another View," by L. C. Ord.

Plant and Equipment :

"Plant Economics," by E. W. Hancock, M.B.E., M.I.P.E., F.R.S.A., F.I.I.A.

"Utilisation of Plant," by J. E. McLaren, M.I.P.E.

A luncheon was held at the Civic Hall, at which Dr. W. A. J. Chapman, President of the Wolverhampton Section, was in the Chair. The toast of "The Success of Britain's Post-War Recovery," was proposed by the Rt. Hon. Lord Sempill, A.F.C., F.R.Ae.S., M.I.P.E.

The full proceedings of this Conference were published in the June issue of the Institution's Journal. This publication has aroused great interest throughout the country, and has done much to focus attention on the vital problem of increasing Britain's production.

3. Education for Management.

After consultations with the Ministry of Education by representatives of the professional bodies concerned, a representative Committee was set up by the Minister, in October, 1945, under the Chairmanship of Lt.-Col. L. Urwick, O.B.E., M.C., to consider Education for Management. This Committee issued a preliminary report in August, 1946, which was carefully examined by the Education Committee of the Institution. A subsequent meeting of the professional bodies concerned was convened by the Minister of Education in December, 1946, when the Institution was represented by a strong delegation, consisting of Dr. H. Schofield, C.B.E., the Rt. Hon. Lord Sempill, A.F.C., Mr. W. C. Puckey, and the Director and General Secretary.

The Institution's delegation advanced the view that it was necessary for students to complete their technical studies in their particular field of engineering before attempting to qualify for higher managerial positions. It was, therefore, suggested that the minimum age for entering upon courses of study leading to the Final Examination in Specialised Management subjects be raised from 23 to 25 years, and that the minimum age for entering upon courses for the Final Examination in General Management qualifications be raised from 25 to 30 years. These amendments were accepted by the Committee and were incorporated in the Report, which was finally published as a White Paper in May, 1947.

In view of the Institution's special interest in Management, Lt.-Col. Urwick was invited to attend the June meeting of the Education Committee, at which he outlined further the aims and intentions of his Committee. In the discussion which followed, many aspects of the Report were considered, and it was agreed that the Report be passed to the Special Sub-Committee of the Education Committee which was preparing the syllabus for the proposed Associate Membership Examination, with a recommendation that the management subjects in the Institution's examination should conform to the suggestions contained in the Report.

4. Technical Films for D.S.I.R.

At the request of the National Physical Laboratory, the Institution is co-operating in the production of a technical film on "Metrology in Industry," which has been commissioned by the Central Office

of Information for the Department of Scientific and Industrial Research. It is hoped that this film will be the first of a series which will be of great educational value in the training of young Production Engineers at technical colleges, and the Institution has played a major part by enlisting help and organising facilities for these films to be made.

5. Jubilee Dinner.

A Dinner to celebrate the 25th Anniversary of the Institution was held in London on 11th March, 1947, with the President, Mr. Norman Rowbotham, C.B.E., in the Chair, and was attended by a fully representative gathering of more than 500 members and guests.

The Rt. Hon. Sir David Maxwell Fyfe, K.C., M.P., who was Assistant Chief Prosecutor at the Nuremberg trials, was the Guest of Honour and proposed the toast of "The Institution" in a speech which was very warmly received. The Dinner was an outstanding success and suitably marked the occasion of the Institution's 25th Anniversary.

6. South African Association of Production Engineers.

An important event which took place during the year was the amalgamation of the South African Association of Production Engineers with the Institution of Production Engineers, which was concluded in January, 1947. In consequence, the Institution now has approximately 250 members in South Africa.

The South African Association agreed to adopt the Institution's Memorandum and Articles of Association, and in joining forces with the Institution, has added to the status and strength of both bodies. The amalgamation took place during the visit of Their Majesties to the Union, and in view of South Africa's industrial progress, no time could have been more appropriate for such a fusion to be brought about.

7. Council Meetings.

It was decided in future to hold Council meetings alternately in the provinces and in London. It was felt that this would not only stimulate interest and enthusiasm locally, but would be convenient for members of Council who are resident in the provinces.

8. Hazleton Memorial Library.

An Appeal has been launched for the formation of a Library to commemorate the late Mr. Richard Hazleton, former General Secretary, with a target figure of £4,000. It is hoped that this figure

will eventually be reached, thus enabling the Institution to establish a Library which will supply Production Engineers with the very latest information from all sources on matters concerning their special activities.

9. Section Activities.

(*a*) *Liverpool Sub-Section.*

In April, 1947, a sub-Section of the Manchester Section was established at Liverpool, under the Chairmanship of Mr. B. A. Williams, O.B.E. The Sub-Section held their Inaugural Function on 26th September, 1947, and have arranged a full programme for the forthcoming session.

(*b*) *Calcutta Section.*

The Calcutta Section is now firmly established with a membership of 31, and many applications for membership have been since received and are under consideration. From reports received, the Institution appears to have a very promising future in India.

(*c*) *New Zealand.*

Efforts are now being made to re-establish a Section of the Institution in New Zealand. All members resident in that country have been put in touch with each other, with a view to furthering this aim and promoting the Institution's activities in that Dominion.

(*d*) *Section Hon. Secretaries Conference.*

A conference of Section Hon. Secretaries was held in Birmingham on Wednesday, 28th May. Many important administrative matters were discussed, including Regional Co-operation, Liaison with the Press, the speeding-up of procedure in connection with applications for membership, and the choice of subjects for Technical Papers.

10. Increase in Membership.

During the year 1946/1947 there has been a net increase of 641 members. The total number of members at 30th June, 1947, was 6,669 ; this is made up as follows :—

Hon. Members	4	
Members	1,190	
Associate Members ...	2,089	
Associates	144	
Intermediate Associate Members...	1,282	
Graduates	978	
Students	776	
Affiliated Firms	206	(Number of Affiliate Representatives, 293)
	6,669	

11. Finance

The Accounts for the year ended 30th June, 1947, show an excess of income over expenditure of £1,204 10s. 7d. as compared with £1,053 7s. 4d. for the year ending 30th June, 1946. This reflects the Institution's healthy financial position. However, as the Institution is now engaged in a wider field of activities, more in keeping with the vital part it must play in the industrial life of the nation, the margin of excess of income over expenditure may possibly suffer a decrease in the future.

12. Institution Medal.

The Institution Medal for the best paper by a non-member was awarded to Dr. J. D. Jevons, B.Sc., F.R.I.C., F.I.M., for his paper on "Difficulties and Developments in Deep Drawing and Pressing." Dr. Jevons is Research Director at Messrs. Joseph Lucas & Co., Ltd.

13. Lord Austin Prize.

The Lord Austin Prize for 1946 was awarded to Mr. R. W. Deutsher, Grad.I.P.E., of Brighton, Victoria, Australia, for his paper on "How Recent Developments in Power Metallurgy during the last ten years have influenced products, and their effect on the work of the Production Engineer." It is the first occasion on which this prize has been awarded to an Australian member. Mr. Deutsher is now Works Manager, and a Director of his firm in Brighton, Victoria.

14. Graduateship Examination, 1947.

Of the 86 candidates who sat for this examination, 68 passed and 18 failed.

15. Technical Enquiries.

The number of technical enquiries appears to be steadily increasing, and in the majority of cases, the Technical and Publications Committee have been able to supply the information required.

16. Honours.

It is recorded with pleasure that the following members have been honoured by His Majesty the King:—

S. O. Hicks, M.I.P.E.	O.B.E.
B. A. Williams, M.I.P.E.	O.B.E.

J. C. Cunningham, M.I.P.E., A.M.I.Mech.E.	M.B.E.
Dr. K. E. Latimer, M.I.P.E.	M.B.E.
R. C. Robinson, M.I.P.E.	M.B.E.
J. R. F. Shand, M.I.P.E.	M.B.E.
W. H. Starr, Int.A.M.I.P.E.	B.E.M.

17. Obituary.

The Institution has suffered a grievous loss in the death of Mr. H. A. Drane, M.I.P.E. Mr. Drane has served the Institution for many years as a member of Council and a member of Standing Committees, particularly the Membership and Education Committees, where his work has been invaluable. He will also be remembered for his work in the Coventry Section, both as President of the Section and as a member of the Section Committee. He was held in the highest respect and esteem by all his colleagues, and his kindly advice and ever-willing help will be sadly missed.

The Institution has also suffered a sad loss in the death of Mr. Wilfred Hill, M.I.P.E., a member of the Manchester Section Committee. Mr. Hill has done valuable work for the Manchester Section, and his loss will be keenly felt.

The death of the following members during the past year is also recorded with deep regret: D. D. Archibald, M.I.P.E., R.Ardaillon, Int.A.M.I.P.E., A. Barber, A.M.I.P.E., C. G. Cornock, Int.A.M.I.P.E., E. C. Farrell, M.I.P.E., H. Johnson, Int.A.M.I.P.E., J. R. T. MacLaren, Int.A.M.I.P.E., A. H. Probert, A.M.I.P.E., W. R. Pullen, A.M.I.P.E., C. Rhodes, A.M.I.P.E., J. A. Rushbrook, Int.A.M.I.P.E., L. G. Scott, Affiliate Representative, E. Smith, M.I.P.E., J. R. Thorpe, M.I.P.E., H. E. Ware, A.M.I.P.E., and M. F. Rowe, M.I.P.E. (Sydney).

"MANUFACTURE AND APPLICATION OF SINTERED CARBIDES"

PART 1. "PRODUCTION AND PROPERTIES"
By E. Trent, M.Met., Ph.D.

PART 2. "APPLICATION IN INDUSTRY"
By H. Eckersley, A.M.I.Mech.E., M.I.P.E.

(*Presented to the Institution of Production Engineers: Western Section, November 15th, 1946; Glasgow Section, December 19th, 1946; Luton Section, January 8th, 1947; Shrewsbury Section, January 23rd, 1947.*)

PART 1. PRODUCTION AND PROPERTIES.

In the twenty years since cemented tungsten carbide was first introduced into this country, most engineers have become familiar with the use of cemented carbides, under one or other of their commercial names, for use as cutting tools or as drawing dies. During the war the production of these materials greatly increased and they are now being used in a much broader field and in many industries, as will be shown in the second half of this paper. The fact that they are now becoming recognised engineering materials for use wherever resistance to wear is required means that engineers should become much better acquainted with their properties so that they can be used to the best advantage.

It is a fact that cemented carbides, as far as the average engineer is concerned, have been shrouded in mystery. It is only in the last few years that the knowledge of their methods of production has been known even to a minority, and even to-day both the nature of the materials and their mechanical and physical properties are largely unknown, except to the carbide manufacturers. This has acted as a deterrent to their employment outside the usual field of tools and dies. It is the purpose of the first half of this paper to dispel some of this mystery.

The Nature of Cemented Carbides.

I will deal first with the "nature" of cemented carbides and how they differ from steels and other tool materials. Metals were first machined with high carbon tool steel. The relatively high hardness (up to 900 Brinell) of heat treated tool steel is due to the distortion of the iron structure which is brought about by the heat treatment. In some cases there are also particles of iron carbide of microscopic

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size dispersed throughout the steel, but these are of only small volume and make little difference to the hardness. The main weakness of plain carbon tool steel is not its room temperature hardness, which is relatively high, but the fact that its hardness drops off rapidly when it is heated to any temperature over 300° C. Not only is the hardness at 300° C. low, but on cooling to room temperature the hardness remains low. Once the tool is tempered, the hardness can only be restored by further heat treatment. The falling off of hardness with temperature is shown in Fig. 1. With carbon tool steels only low cutting speeds could be used, where the temperature at the cutting edge did not exceed the temperature at which the hardness of the tool dropped rapidly.

The development of the alloy tool steel compositions containing first chromium and then increasing proportions of tungsten, molybdenum and other alloying elements, resulted in big improvements. The culmination of developments along these lines was reached with the high speed steel which about 45 years ago created a sensation by cutting steel with the cutting edge at a red heat. The high speed steels were no harder at room temperature, and in many cases were softer than plain carbon tool steels. Their advantage lay in the fact that they retained their hardness to a much higher temperature. As shown in Fig. 1 they lost hardness seriously only at temperatures over 600° C. and it was only after tempering to over 600° that the loss in hardness was retained at room temperature.

The micro-structure of a hardened high speed steel is shown in Fig. 2, at a magnification of 500 times. The background or matrix of this material consists of an iron alloy containing also chromium, tungsten, vanadium and carbon. The crystal structure of this matrix has been distorted by the heat treatment and is therefore hard, as in the case of the carbon steels. The main function of the alloying elements is to stabilise this hard structure up to temperatures of 600° C. Dispersed throughout this matrix are small particles of a double carbide of iron and tungsten, as can be seen in Fig. 2 (one particle is indicated by an arrow). These carbides are considerably harder than the matrix and contribute something to the wear resistance of the steel, but they are present only in small proportion and so only modify the properties of the steel to a relatively small extent.

With the high speed steels the development of alloy steels reached its peak and only comparatively small improvements have since been achieved in this type of alloy. The hardness of materials of which the major constituent is iron seems to be capable of little further improvement and the softening temperature can be raised only slightly over 600° C.

Research was turned in the direction of using some metal other than iron as the major constituent and a series of alloys based on

cobalt as the major constituent was put on the market in the 1920's. The first of these were the " Stellites " which were made in various grades of hardness. In general, their room temperature hardness was not higher than that of high speed steel, but they retained their hardness to a rather higher temperature (see Fig. 1) and also possessed other desirable qualities, such as high resistance to oxidation and corrosion. In these alloys the matrix consists of cobalt alloyed with chromium and tungsten, and dispersed within this matrix are coarse and fine particles of carbides which are much harder than the matrix and appreciably affect the hardness of the cobalt alloy. However, the carbides are present in only relatively small proportion and full use is not made of the intense hardness of these substances.

It has been known for a long time that these carbides which occur as a minor constituent in steels are very hard and that another carbide, tungsten carbide, is among the hardest substances known. It was not until more than 20 years after the introduction of high speed steels that a method was developed for utilising the intense hardness of tungsten carbide. The main difficulties lay in the very high melting point and the brittleness of this substance.

The melting point of tungsten carbide is over 2,500° C. By using special types of electric furnace it is possible to melt the carbides of tungsten and to produce shapes from these materials by casting. In fact, this process is in use to-day and sandblast nozzles, for instance, are frequently produced in this way. The hardness of cast carbide is of the order of 2,000 Vickers—very much higher than any iron or cobalt-based alloy—and, as would be expected from the high melting point of the carbide, the hardness is retained to very much higher temperatures. But it is difficult to produce any but simple shapes by casting and the cast carbides are brittle. One reason for their brittleness can be seen in Fig. 3, a micro-section of a cast carbide at a magnification of 500 times. The grain-size is extremely coarse and uneven. They are unsuitable for use as cutting tools for this reason and do not take a sufficiently good polish for use as drawing dies.

It was in the methods of powder metallurgy that the solution to the problem was ultimately found. Tungsten metal for lamp filaments was already being made from tungsten powder. It was found to be moderately easy to produce tungsten carbide as a fine powder. When tungsten carbide powder was mixed with a proportion of cobalt or other metal powder, pressed into a compact and heated above the melting point of the lowest melting constituent, a range of alloys could be produced, much stronger than cast carbides and nearly as hard. In these materials the properties were determined mainly by the tungsten carbide, which was the main constituent, and only to a minor extent by the softer cobalt metal

which acted as a cement binding together the particles of carbide. (Fig. 1 shows that not only is the room temperature hardness much higher than that of steels, but the hardness is retained to a much higher temperature.) Not one single alloy but a range of alloys was formed whose properties could be varied by adjusting, within limits, the percentage of cobalt. Fig. 4 shows the structure of a cemented carbide of coarse grain, the grey geometrical shapes being the carbide particles, and the whiter matrix the cobalt. Although the grain-size is much coarser in Fig. 4 than in normal cutting tools, it will be obvious that it is much finer than that of a cast carbide if it is compared with Figure 3 of which the magnification is only 500 times as against 1,500 times for Fig. 4. This question of grain-size will be dealt with later.

It has since been found that other hard carbides, in particular titanium carbide, confer special and very useful properties to the alloys. By varying the composition of the carbide, the proportion of cobalt to carbide and the grain-size, a wide range of useful properties can be obtained.

The Method of Production of Cemented Carbides.

In practically all commercial cemented carbides the main constituent is tungsten carbide. The first process is the production of tungsten metal powder by methods similar to those used in the lamp industry. Tungstic oxide, or ammonium paratungstate, in the form of powder of high purity, is heated in an atmosphere of hydrogen at 800° C.–900°C.

This first stage is one of the most critical steps in the process, because the grain-size of the tungsten metal largely determines the grain-size of the final product. The aim is to produce a tungsten metal powder of fine and even grain-size, the particles of tungsten being of the order of 1 micron (0.001 mm.). Great care must be taken to keep constant all the conditions of reduction—the temperature of the furnace, the flow of hydrogen, the weight of tungsten per boat, and the rate at which the boats or trays are pushed through the furnace.

The depth of the layer of tungsten salt or oxide in the boat is an important factor. To achieve uniformity, only a thin layer of tungstic oxide can be placed in the boats and a satisfactory tungsten metal can only be produced in small units as shown. The small batches in which the process is operated throughout is one of the reasons why the product is not a cheap one. Another reason for this is that nearly all the heating operations have to be carried out in an atmosphere of hydrogen of high purity. For some operations it is essential that the hydrogen be free from oxygen and with the moisture content reduced to a dew-point of —50° C. This requires special hydrogen purification and drying plant.

The tungsten metal is generally produced in batches of about 100 lbs., each batch being checked for grain-size at this stage. To maintain a reliable product, laboratory checks must be taken at several stages in the production of each batch of powder. The amount of chemical analysis and other laboratory work required per pound of metal produced, is much higher than in most metal production.

After laboratory checks, the tungsten metal is converted into the hard compound, tungsten carbide, whose chemical formula is WC. This is done by mixing together tungsten metal and carbon (in the form of lampblack) in the correct proportions, in ball mills or mixers with rotating paddles. The mixed powders are placed in carbon boxes or "boats" covered with well-fitting lids and heated to approximately 1,500° C.–1,600° C. for an hour or more, in an atmosphere of hydrogen. For this operation, continuous type furnaces are generally used, in which the work is pushed continuously through the hot zone of the furnace and into a cooling jacket, where it is cooled in hydrogen to room temperature. Two main types of furnace are used for these high temperatures. In one a refractory tube is heated electrically through a winding of molybdenum wire. In the other a carbon tube, through which an electric current of very high amperage is passed, forms both the heating element and the furnace chamber.

The tungsten carbide is removed from the furnace in the form of a loose cake which can easily be crushed to a powder. This should contain 6.12 per cent. of combined carbon with as little free carbon as possible.

The cobalt metal which is to form the bond cementing together the carbide particles, is produced in powder form by a similar process to that used for tungsten. High purity cobalt oxide is reduced to cobalt by hydrogen at about 600° C.–700° C.

The other main constituent of many cemented carbides is titanium carbide. This can be made from the raw material, titanium dioxide, in one stage by heating to 2,000° C. with carbon in the form of lampblack. Specially designed carbon tube furnaces are used for these extremely high temperatures.

It is one of the advantages of powder metallurgical processes that they offer the maximum control over the composition and purity of the product. Having prepared the components in the form of high purity powders, these can be mixed to produce accurately the desired composition and the losses sustained in the subsequent operations are much smaller and less erratic than those involved in melting.

The mixing, which is another key stage in the process, is carried out in ball mills such as that shown in Fig. 5. The weighed powders, together with several times their weight of cemented carbide balls,

are placed in the mill with sufficient distilled water to make the powder into a thin paste. The ball mill is sealed up and rotated for several days. It is essential that the powders shall be thoroughly mixed so that every particle of carbide shall be adjacent to a particle of cobalt. Every cluster or aggregate of particles is broken down and some reduction in grain-size takes place.

The last steps in the preparation of the powder are the drying and sieving operations. Drying must be carried out either in hydrogen or under reduced pressure. If the powder is dried in air it will generally ignite and burn readily.

After drying, the powder is caked like dried mud, and must be sieved through a fine (200 mesh or finer) sieve to break up the cakes. In some cases a pressing lubricant is added to the powder—some material such as paraffin wax which does not affect the quality of the powder but which assists in the production of good compacts free from cracks.

While the powder is stored ready for use it is analysed and test-pieces are sintered from the powder, so that the ultimate hardness and other properties of each batch are known before the powder is used for the production of tool tips, drawing dies, or other components.

To produce useful shapes from the loose powder the simplest method is to make a die of the desired shape, fill it with the correct weight of powder, and press it at such a pressure that the compact will hang together. Pressures between 1 and 15 tons per square inch are required. The range of sizes produced is great, so that a series of presses of varying capacity is required. Anything like large scale production requires the use of rapid acting automatic presses.

For a number of reasons, only relatively simple shapes can be produced by this method. The main reason is that carbide powders, and, in fact, all metal powders, do not flow readily under pressure in the way that plastics do. They will not flow readily in a direction at right angles to the direction in which pressure is applied. Thus re-entrant angles and holes at right angles to the direction of pressure cannot in general be moulded in. A wider variety of shapes can be produced by using complex dies with independently moving parts, but the variety of shapes which can be produced by direct pressing is limited.

In the final operation, sintering, the compacts contract so that the linear dimensions in each direction are reduced by about 20 per cent. The problem of pressing is further complicated by the necessity of making allowance for this contraction. One of the reasons for the close control of all the operations involved in the powder production is that the contraction of the compacts during sintering must be maintained as nearly constant as possible for every batch of powder. The contraction which takes place during sintering depends not

only on the grain-size, etc., of the powder, but also on the pressure at which the compacts are pressed. Thus, if even contraction in all parts of a compact is to be achieved, and warping avoided, all parts of the compact must be pressed at the same pressure.

Not all the pressure is transmitted from the top of the powder compact to the bottom, some being taken up in friction between the powder and the wall of the die. This problem becomes serious if a long thin piece must be pressed in the direction of the longitudinal axis. In this case the pressure at the bottom may be only a fraction of the pressure at the top, and contraction at the bottom will be much greater than at the top on sintering. This must be taken into consideration when designing the dies. Correct die design is a most important part of the process. The dies are expensive, and a special die for a non-standard tool tip or other component can only be warranted if very large numbers of the component are required.

Sufficient has been said to show that the simplest and most obvious method of producing compacts is strictly limited in its application. This does not mean that only such a limited variety of shapes and sizes can be made. Other methods have been worked out and pieces of large size and complicated section can now be produced.

The most important of these methods is particularly useful for the production of components of which very large numbers are not required. A large block of carbide is pressed and the pieces are machined from this before sintering. The pressed block is too fragile to be safely handled, but it is found that, when heated to 700°–800° C. in an atmosphere of hydrogen, the block becomes hardened to something like the consistency of chalk. It can then be cut with elastic wheels, ground, machined with carbide or diamond tools, drilled or formed by almost any workshop method.

It is obvious that this method greatly extends the range of shapes and sizes which it is possible to produce. For large sizes very large presses of 1,000 tons or more capacity are required, and this imposes an economic limit to the size of pieces which can be produced by these methods.

The final operation of sintering converts the soft, fragile compact to an extremely hard, dense component. The sintering operation consists of heating the compacts to a temperature of 1,400°–1,600° C. for an hour or more in an atmosphere of hydrogen, or in vacuum. Sintering can be carried out in the same type of furnace as is used for carburising.

What happens during sintering? How does such a dense, hard material result from this treatment? Much research has been carried out on this subject, but there is still much to learn. Shrinkage begins to take place at 1,200° C. and is practically completed at 1,400° C. This is well below the melting point of the cobalt (1,490° C.) but it appears that the cobalt reacts with a small proportion of the

tungsten and carbon to form an alloy which melts at about 1,320° C. This molten alloy wets the remaining tungsten carbide powder and draws it together by surface tension. It is essential that this process should take place practically simultaneously throughout the mass being sintered if warping and cracking are to be avoided. Thus the pieces must be heated slowly and care must be taken that the temperature gradients are not too steep. At the sintering temperature the compacts are soft and plastic and must be firmly supported to prevent them bending under their own weight.

The sintering operation introduces further limitations on the shape and size of components which can be easily produced. Very large pieces and long pieces of thin section are difficult to sinter and to maintain straight. To overcome these limitations the hot-pressing process has been introduced. In this process the pieces are inserted under pressure so that the carbide is forced into the shape of a graphite mould while in the plastic condition at the sintering temperature. In this way, thin discs, long thin rods and rings up to 20 in. in diameter can now be produced.

On cooling down after sintering the pieces have achieved their final properties which cannot be altered by heat treatment. No further treatment is required to harden them, nor can they be softened by annealing. The hardness is an inherent property of the carbide, which forms the major constituent of all these materials. Close attention to shape and dimensions before sintering is essential because the great hardness of the sintered product makes it impossible to machine and difficult to grind, even using diamond wheels. It is undesirable to have to remove more than a few thousandths of an inch from the surface after sintering.

The Properties of Cemented Carbides.

As emphasised above, all sintered carbides are relatively hard, but the available commercial carbide grades cover a wide range of mechanical properties. The mechanical properties of any alloy are mainly determined by three factors : the proportion of cobalt metal in the alloy, the grain-size of the carbide particles and the presence of other carbides apart from tungsten carbide.

The relationship between the cobalt content and the mechanical properties of tungsten carbide-cobalt alloys containing from 3 to 20 per cent. of cobalt is shown in Fig. 6. The graphs represent the average of a large number of laboratory tests and are neither the highest nor the lowest properties found in commercial alloys.

As the cobalt content increases from 3 to 20 per cent. the hardness drops from 1,900 to 1,000 Vickers. Thus the softest carbides normally produced are of about the same hardness as the hardest steels.

The carrying out of tensile tests on cemented carbides is difficult and the interpretation of the results is uncertain, because of their lack of ductility. The strength therefore is normally measured by a transverse rupture test similar to that used for cast iron but on much smaller test-pieces. The results are recorded as the transverse rupture strength in pounds, or tons, per square inch. Fig. 6 shows that as the cobalt content is increased the transverse rupture strength increases, reaching a maximum of 19 to 20 per cent. Co with a value of more than 150 tons per square inch.

The transverse strength is high but it is the compressive strength which is most exceptional—this varies with the cobalt content in a similar manner to the hardness, and with a low cobalt content reaches a value over 375 tons per square inch.

Similarly, the modulus of elasticity is very high compared with that of steels. It varies from over 90×10^6 for an alloy with 3 to 4 per cent. Co to 75×10^6 pounds per square inch for an alloy with 20 per cent. Co. This is approximately three times the modulus of steel.

To turn from those properties where carbides excel to those where they are relatively inferior, the main weakness is that they have practically no ductility at room temperature and that their resistance to shock loads or impact is poor compared with that of steel. The resistance to impact loading increases as hardness decreases—it is the alloys low in cobalt which are most brittle, and those with 15 to 20 per cent. Co are much more shock resistant. In general, if one of the hardest cemented carbides is required, account must be taken of the fact that it will be relatively brittle, and impact loading, especially on sharp corners, should be avoided.

Another weak point, which is of concern in only a few applications, is the relatively low oxidation resistance of carbides in air at temperatures over 650° C. Scaling is very rapid at these temperatures and care should be taken in such operations as brazing, to protect the tool from oxidation. Unlike steels, they are not decarburised under the scale, and a surface from which scale has been removed retains its full hardness.

As has already been mentioned, the carbides are not only hard at room temperature but retain their hardness to a much higher temperature than do other tool alloys. This is the main reason why they can be used as cutting tools at such high speeds.

The properties can be modified by altering the grain-size of the carbide particles. Fig. 4 shows a coarse-grained and Fig. 7 a fine-grained carbide, the photo-micrographs both being at a magnification of 1,500 times. In general, the finer the grain-size of the carbide, the higher the hardness. By decreasing the grain-size and maintaining the same cobalt content; the hardness can be increased while the

strength remains the same or is only slightly decreased. For this reason the modern tendency in these alloys is to produce finer grain sizes.

Other properties of carbides which are of importance in engineering include their coefficient of thermal expansion. This is of the order of 6×10^6, which is approximately half that of steel. The thermal conductivity is high, being considerably higher than that of steel.

Cemented carbides are excellent for wear-resisting parts and for this purpose their value is increased by their ability to take a high polish. This is particularly useful in the case of wire-drawing and other dies where it results in a reduction of the coefficient of friction.

Finally, a few remarks concerning the use of other carbides apart from tungsten carbide. The most common of these is titanium carbide which is added together with tungsten carbide to the grades which are used for machining steel. It is due to the use of this carbide that there is such a proliferation of commercial carbide grades. The result of adding the necessary amount of titanium carbide in terms of cutting efficiency is extraordinary, but the reason why titanium carbide produces this effect is not obvious. It causes no increase in hardness and the strength is actually reduced. There is also a reduction in thermal conductivity. The most likely explanation seems to be that titanium carbide welds less readily to the steel being cut than does tungsten carbide, and therefore prevents cratering of the carbide at the cutting edge.

In conclusion, the aim of this brief survey of the manufacture and properties of the cemented carbides has been to illustrate the manufacturer's side of the problem—the control of a unique type of metallurgical process for the production of a consistently high-grade product—and to give some idea of the mechanical and other properties of materials which are just making their way into the field of general engineering.

PART 2. APPLICATION IN INDUSTRY.

The application of sintered carbide cutting tools in engineering production has been familiar to Machine Shop people and the Wire Drawing Industry for approximately eighteen years, and experience, therefore, is widespread. It will not be out of place, however, to elaborate on the necessity for discrimination in the choice of grades for cutting various materials, particularly in view of the inclusion of materials hitherto unfamiliar to the general type of work going through the average machine shops.

As has already been pointed out, sintered carbide tools should be divided broadly into two types—straight tungsten carbide and tungsten carbide with other alloyed elements. The first-named is

generally used in machining cast iron, non-ferrous alloys, plastics, asbestos, wood, stone, glass and other materials where extreme abrasion is experienced, whereas it has been found that steel alloys containing some percentage of tungsten, chrome, nickel or molybdenum require to be cut with tungsten carbide having an addition of titanium. This is to combat the tendency for build-up of swarf dust on the cutting edge, leading to rapid breakdown due partly to change in direction of chip pressure on the cutting edge. It is also important to recognise the necessity for choosing correct tool shapes for maximum life. A tool with the cutting edge at right angles to the axis of the workpiece for turning, for example, has not the same metal removing capacity between grinds as a tool with the cutting edge pitched at 45° to the axis of the work. The reason lies in the distribution of pressure along the cutting edge being such that in the first case unit pressure is very much higher than in the second case. It is obviously desirable that the unit pressure be kept at a minimum, dependent upon the requirements of the cut on the job. A good example of the necessity for consideration of this point is the turning of chilled iron rolls and glass, both being hard and brittle materials.

It was common practice in the days when high speed tools were used on this kind of work, to run at speeds in the neighbourhood of 4 ft. per minute in the case of chilled iron rolls, whilst glass was turned at speeds in the neighbourhood of 20 ft. to 60 ft. per minute. On the better type of roll-turning lathe, tools are used with a length of cut approximately five times greater than the actual depth of cut, as shown in Fig. 8 (B). The adoption of sintered carbide tools for this operation has enabled speeds up to 25 ft. per minute to be obtained with an additional increase of life of approximately three times, giving a nett overall improvement in performance of twenty-four to one ; similar improvements were obtained in the glass industry.

Five common types of cutting tool shapes are illustrated in Fig. 8. The round-nosed tool, as will be observed from the graph, absorbs more horse-power than tools with a straight cutting edge ; that is, the production of a flat ribbon type chip is more economical in power than is the tool which produces a curved chip. The reason for this is that a curved chip, in being bent to follow the top rake of the tool, induces high pressure between itself and the tool, with an increase in the friction set-up, and, of course, a certain amount of effort is required to bend the chip in excess of the effort necessary to bend a flat chip. The graph illustrates the approximate differences in horse-power consumption using tools of the four shapes shown. It will be appreciated, of course, that where the feed is common the chip thickness is reduced as the angle of approach is increased. Area of cut is the same in each case. An extreme approach angle under

conditions of heavy feeding in a machine which is over-powered may induce considerable chatter where a lengthened cutting edge is employed. This does not apply to machines of modern design, generally speaking, but only where machines of low cutting speed and low horse-power capacity are in use. Increase in cutting speed up to the limit of tungsten carbide can often dispose of chatter conditions under these circumstances.

There is a growing tendency for cutting tools to be used employing primary and secondary top rake, as shown in Fig. 9, the object of which is primarily one of standardisation of top rakes, at 8° in most cases, so that where a reduction in top rake is necessary for cutting the harder materials, the top rake existing on the tool can be treated as a secondary top rake, and a primary top rake ground on the tool by a simple operation, producing the equivalent of a land not more than perhaps $\frac{1}{16}$ in. in width, in which case the tool will cut with a reduced horse-power consumption. This method has the advantage of simplicity in reconditioning, and a land can be finally lapped with a diamond wheel having a fine diamond grain-size to provide a superfine finish, which in turn again reduces horse-power consumption and increases life of the cutting edge.

An interesting development in milling has been the application of sintered carbides to the machining of aluminium alloys. In this material, astonishing results have been obtained, milling feeds up to 15 ft. per minute being possible, with cutting speeds up to the maximum a machine can produce. A milling operation, carried out for over three years during the war in an aircraft factory, employed carbide cutters running at 9,500 ft. per minute, with a feed rate of 3 ft. per minute, the feed rate being limited by the design of the machine tool feed box. Under these circumstances, 200 hours continuous milling between re-laps of the cutter were established practice throughout the period.

The set-up in Fig. 10 illustrates the application of a milling cutter in the machining of aluminium alloy motor-car crankcases, cutting at approximately 4,000 ft. per minute, with a feed rate of 60 inches per minute. Cutter life between re-laps is in the neighbourhood of two months in this instance. A flywheel is shown mounted behind the cutter, but it is not strictly necessary where high peripheric speeds are obtainable, when the milling cutter body provides flywheel effect. Similar efficiency is, of course, obtainable in turning and other operations using cemented carbide tools, but no one need ever fear running at too high a cutting speed on any aluminium alloy under any kind of machining condition. The cutting speed is not a limiting factor of performance. At the present moment, machine spindle speeds are far too low to enable tungsten carbide tools to be exploited to the maximum, but even so, good modern machine tools will show astonishing increase in output where

tungsten carbide is used on such materials. General practice is to run at the top speed at which the machine is capable of running. Milling machines invariably run with the top feed employed, whilst lathes can employ feeds up to the maximum the job will stand. Horse-power consumption is usually in the neighbourhood of 10 cubic inches of metal removed per horse-power per minute, employing a true top rake of 15° positive. Titanium grades are usually used in cutting aluminium alloys, to combat the tendency for "build-up" of the swarf dust on the cutting edge.

A new design of Face Milling Cutter employs the principle of primary and secondary top rakes, where these are necessary. (Fig. 11)

The construction of the cutter employs solid tungsten carbide blades, fixed by a wedge and screw in a tough steel body. This is a recent development arising out of the considerable experience of milling a wide variety of materials since 1939. One of the inherent disadvantages of tungsten carbide cutters in the past has resulted from the stresses in the tip induced by brazing the tungsten carbide to a steel shank. The solid tungsten carbide blade is obviously free of such stresses and it has been proved that heavier tooth loading can be employed in this case, than with the brazed tip type of cutter. Extensive experience and application on a wide variety of materials has also proved that the negative helix angle is extremely important in milling (see the author's paper, "Negative Rake Milling," published in the Journal of the Institution in November, 1945) and this design of cutter employs that principle. The radial rakes, however, are positive so that Cutter "A" can be used on cast iron and non-ferrous materials such as brass, phosphor bronze, etc., without modification. Where higher cutting pressures are encountered, however, such as in the machining of medium and high tensile steels, a zero or negative radial top rake can be employed by modification of the cutting edge with a simple lapping operation, producing a land of 0.03 in. wide, or thereabouts, in the same fashion as described in Fig. 9.

In this case, fewer teeth are usually required, as shown in Cutter "B", because the cutting speeds employed with Cutter "A" are usually in the neighbourhood of 250 ft. per minute, in the case of cast iron, up to about 400 ft. per minute for non-ferrous materials other than aluminium alloys, whilst steel is usually cut at speeds between 400 ft. per minute, up to 1,000 ft. per minute and therefore the obtainable feed rate per revolution of the cutter is approximately double in the case of Cutter "B" as compared with Cutter "A". Reduction in the number of teeth, therefore, is desirable, as the feed rate per tooth will usually be similar in each case.

Aluminium alloys can also be machined with a cutter of type "B", in which case, of course, the positive radial rake will be employed, at the maximum possible cutting speed, with a feed per tooth not less than 0.005 in.

The cutter shown in Fig. 12 employs similar principles to those outlined above, but in this case the cutter is designed for slot milling and such a cutter is capable of the very heavy loading encountered in deep slot milling, similar to that met with in the production of turbine rotors. The inserted blade type of cutter is practicable in this design, down to about $\frac{1}{2}$ in. width of cut, below which tips brazed to a solid body must be used. Cutters below $\frac{1}{8}$ in. in thickness must be designed as a saw, with the body tensioned in the normal saw practice, to ensure true running of the cutting edges at the speed for which the saw is designed.

An interesting design is shown in Fig. 13 of a cutter for light slab milling with depth of cut up to about $\frac{1}{16}$ in. It will be seen that tungsten carbide inserts in the form of woodruff keys are employed, brazed in position in milled slots. The teeth are so laid in the cutter that at the entry end of the cutter, negative radial rake exists and this gradually changes throughout the length of the helix, becoming positive radial rake at the exit end of the cutter. This assists the removal of chips with minimum horse-power consumption and the cutter is quite successful under suitable conditions. No keyway is necessary to drive the cutter, even though the tooth loading is high, and length of engagement of the cutter is great, indicating the smoothness of cut during revolution.

The Slot Drilling Cutter shown in Fig. 14 was developed for routing or the production of key seats, and operates partly on a trepanning principle. The design enables the tool to be used for initial penetration to depth and subsequent traversing using both routing and key seating cuts, with a good finish on the workpiece, and a rapid metal removal rate without variation beyond normal tolerance in the width of cut. All holes and slots shown in Fig. 14 were produced with the cutter shown.

The sheet metal and wire industries employ rolls of various types for several purposes; amongst these are the cold rolling of strip, the flattening of round wire and the forming of half-round wire from round wire. The latter operation is carried out on rolls which comprise a pair—one of which is grooved and the other plain. The abrasion of this type of work is exceedingly high and the application of tungsten carbide to this type of tool has been most successful.

The attachment of the tungsten carbide by the orthodox method of brazing is entirely unsatisfactory, because of the risk of pockets in the brazing film reducing the total area of support of the tungsten carbide. The metal to metal direct contact is achieved by using the

deep freezing process on the core, so that an interference fit is obtained when the core regains room temperature. It is obviously necessary that the bore of the tungsten carbide ring and the outside diameter of the core be a first-class grinding job, to ensure continuity of contact over a considerable surface area. The roll illustrated in Fig. 15 is made up of separate abutting sleeves, with sleeves of similar length mounted on the plain roll.

Rolls up to 14 in. diameter have been successfully made and Fig. 16 shows a pair of rolls designed for the production of strip. This type of roll requires edge protection and this is achieved by the application of flanges in steel, but the mounting of the tungsten carbide is also achieved by using the deep freeze process.

Rolls of this type are usually finished to a profilometer measurement of 0.5 to 1 micro inch surface finish and this accuracy is essential to ensure reproduction of this quality on the work produced, resulting in a superior product unobtainable by other means.

Because of the high compression strength of tungsten carbide it has been found in many cases that great reductions in strip thicknesses are possible with tungsten carbide rolls, with consequently fewer passes to obtain the final strip size. The life of these rolls is greatly in excess of that of steel rolls and installation in many factories has shown considerable economy following their adoption.

Slitting discs designed on similar lines are in use on a variety of materials, including steel, and because of the ability of tungsten carbide to retain its cutting edge for a very long period, burr free strip is obtained, with the "velvet" edge which the trade has always striven for.

There has also been considerable misconception regarding the ability of tungsten carbide to withstand shock and the following examples will prove the economy of tungsten carbide under shock loading conditions where the tool is correctly designed to withstand that shock. Fig. 17 shows tools used in the production of nails. This type of tool is common in the manufacture of parts requiring heading and cutting-off. The method of operation, at the rate of 150 to about 800 reciprocations per minute, is as follows :—

Wire is gripped between two gripper tools, carrying serrations in the groove, which embed themselves in the wire whilst a hammer comes forward and produces a head. This action is followed by the pointing tools coming together and cutting-off the wire, at the same time as the point of the nail is formed in the same tools. The first installation of this type resulted in failure of the shank of the hammer, whilst the tungsten carbide was in perfect condition. A change in material of the hammer shank has eliminated this trouble. Another point of failure was in the breakdown of the serrations in the tungsten carbide insert on the gripper tools, but only after a

reasonable economy of life had been established. Subsequent installation of similar tools has given remarkable results in performance on small nails at high speeds, that is, production of approximately 600 nails per minute. Where heavier wire is in production, dimensional problems project themselves and these are at present the subject of research, but there is no doubt that success will very shortly be achieved for a full range of products of this nature.

An example of fine tool making in tungsten carbide is shown in Fig. 18, which illustrates the component parts in tungsten carbide of a piercing tool for components of complicated form. It will be noticed that small wings of tungsten carbide on the main punches are very delicate, and it would be expected that these wings would break off on impact of the punch with the stock. Press tools are an economical investment in tungsten carbide. It is usual in blanking and piercing tools of this nature to incorporate tools in a die set with built-in tungsten carbide pillars and bushes for maximum life of the punch and die.

Press tools for blanking and piercing are now in use in a number of factories producing laminations and similar parts, both here and in the U.S.A., and have proved to be economical applications of tungsten carbide. Although the first cost is relatively high, being approximately four times that of steel tools of similar design, life advantage from ten to fifty times is regularly proved.

Other developments since the war have included the production of percussion rock drills for use in mines and quarries where granite and other hard rocks are encountered, when drilling for shot blast holes. Penetration of a drill of this type is approximately 1,800 feet, as compared with 25 ft. for the best possible steel drill rod. Detachable heads with tungsten carbide inserts, as shown in Fig. 19, are in use in British coalfields and South African gold mines, showing established economy. These drills operate at approximately 2,000 blows per minute, and are, of course, rotated slowly during percussion drilling.

The foregoing examples of percussion loading on tungsten carbide is an indication of the qualities of physical properties outlined in the graph in Fig. 6 of the first part of the paper. Tungsten carbide may break if loading is eccentric or localised on the cutting edge, but if the direction of pressure can be arranged in such a way that the body of the tungsten carbide metal can absorb the load, then tungsten carbide has high resistance which can be exploited in many directions. Other examples of shock-loaded tools include cold heading dies for bolts, swaging tools, spring forming tools, cut-off tools for wire, stone chisels, caulking tools, shear blades, etc.

Presswork dies are now extensively used employing tungsten carbide, and Fig. 20 shows an interesting example of this type of

work. In this case, tungsten carbide in the form of slabs are mounted in a die holder by interlocking tenons and vee clamping strips. If the tungsten carbide strips are brazed to the die holder in such a tool, the rate of thermal expansion of tungsten carbide being only half that of steel, the braze would be highly stressed during cooling, and the tungsten carbide would probably crack due to the restrictive "pull" of the braze. The method of mounting the tungsten carbide in this tool ensures that the tungsten carbide is entirely free of induced stress, excepting when in actual work. Thus the wearing surfaces can be relied upon to supply maximum resistance to drawing pressures, without dispersal of strength. Steel tools have previously been replaced after 500 metal components in the form of boxes have been drawn in the die as wear at that quantity was excessive. The tungsten carbide tool shown has produced approximately 50,000 boxes to date with no measurable wear on the die. This principle is capable of considerable exploitation where segmental drawing dies are required, and while initial cost is obviously higher than that of steel tools, the ratio of life entirely justifies the adoption of tungsten carbide for this type of work. Where drawing dies have been used for such work as domestic hollow-ware, cases are on record where millions of components have been drawn from the die without measurable wear, and in addition, because of the capacity of tungsten carbide to take a very high finish, reduction in finishing operations on components is possible, and this saving alone has, in a large number of cases, paid for the installation, without taking account of the considerable life increase of the tool.

Tungsten carbide is now applied very widely to cutting tools employing fine cuts, such as those experienced in jig boring and on watchmakers' lathes, Swiss automatics, etc. It is good practice in cases of this kind to super-lap the cutting edges of the tools, using a 400 grit diamond wheel. Finishing a tool in this fashion results invariably in a life increase of three times, or thereabouts, enabling tolerances to be maintained over a very much longer period.

There is insufficient time to describe the very considerable applications for resistance to wear, other than to say that tungsten carbide is now used in textile machinery producing yarns in flax, jute and sisal, with resistance to wear superior to that obtained with glass and synthetic materials. Other examples where life increase justifies the expense of tungsten carbide are as follows:—feeder discs and fingers for press tool stock and wearing strips in reciprocating parts; tools for making springs and other wire products where high abrasion in bending wire is encountered; balls for hardness testing instruments are made in tungsten carbide, produced to tolerances of 0.0001 in.; drawing dies for wire, bar and tube; gauges of all types; wear strips for use in conjunction with standard slip gauges and very many more applications.

It is now possible to produce welding rods in the form of tube filled with crushed cast carbide, and which can be used for hard facing surfaces which do not require subsequent machining. It is not too easy to deposit this material without risk of porosity, which might interfere with the correct functioning of a machined surface, so that its application is generally confined to earthworking tools and the like. The characteristics of these filled rods are such that high resistance to abrasion is an outstanding feature of their application but resistance to high concentrated pressure, as experienced in cutting tools, is not good in the deposited material. Where the material can be deposited with considerable skill, grinding with silicon-carbide wheels or diamond impregnated wheels may produce a surface suitable for certain cases where sliding friction is experienced.

In conclusion, the author suggests that only a fringe of the field for use of tungsten carbides and their variants has so far been touched and the examples given in this paper may serve to justify this claim. Only a representative selection of applications has been possible, but they may serve to show the scope of tungsten carbide in industrial fields. In these days of manpower shortage, it is essential to conserve all effort and to increase productive capacity to the limit and tungsten carbide provides a generous means of achieving these ambitions.

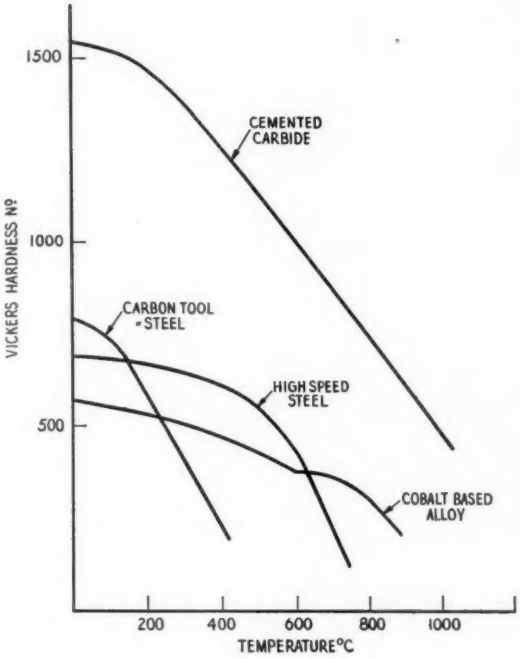

1500
1000
500
VICKERS HARDNESS Nº
CEMENTED CARBIDE
CARBON TOOL STEEL
HIGH SPEED STEEL
COBALT BASED ALLOY
200
400
600
800
1000
TEMPERATURE °C

FIG. 1.

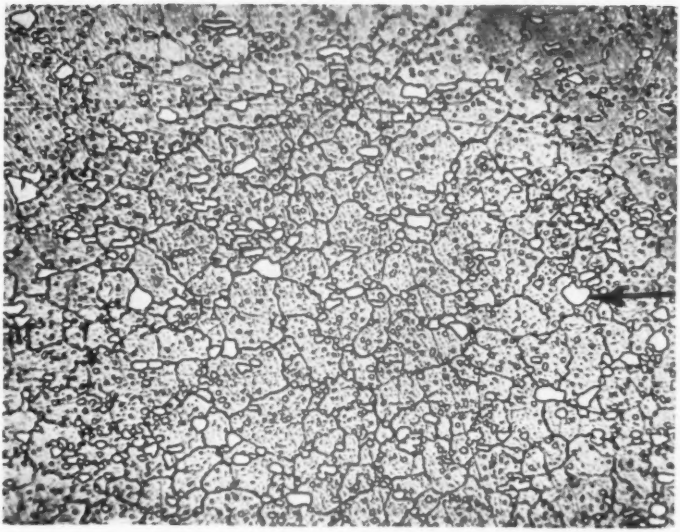


FIG. 2.

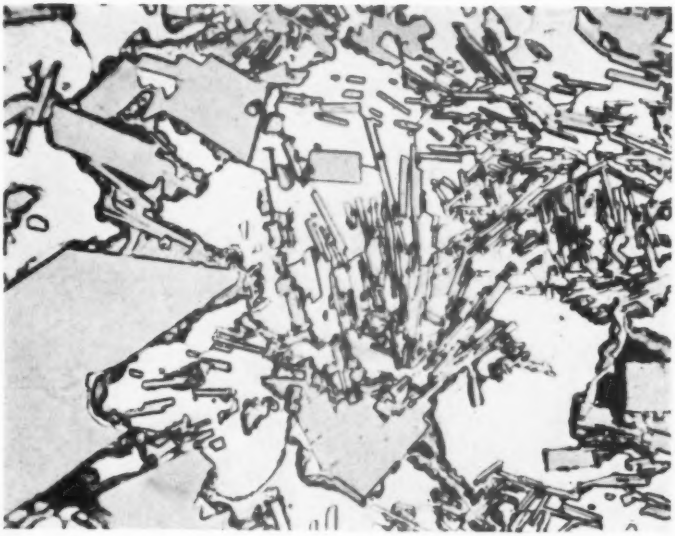


FIG. 3.

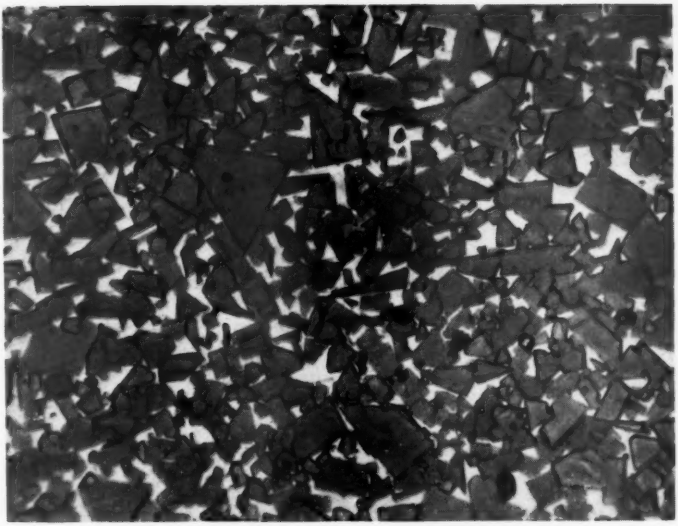


FIG. 4.

FIG. 5.

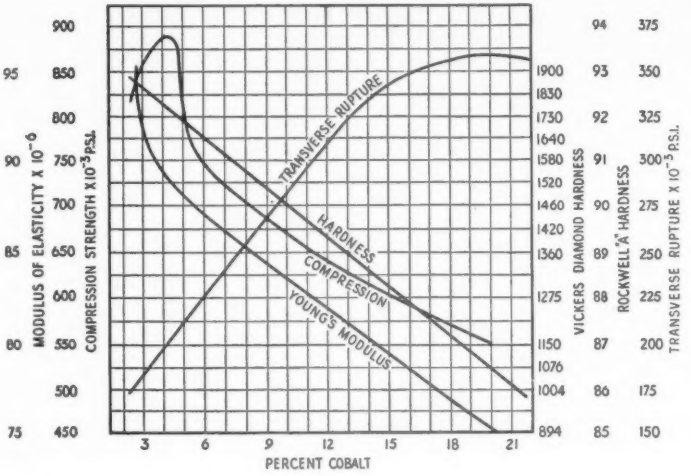

MODULUS OF ELASTICITY X 10⁻⁶
COMPRESSION STRENGTH X10⁻³P.S.I.
VICKERS DIAMOND HARDNESS
ROCKWELL "A" HARDNESS
TRANSVERSE RUPTURE X 10⁻³P.S.I.
TRANSVERSE RUPTURE
HARDNESS
COMPRESSION
YOUNG'S MODULUS
PERCENT COBALT
95 90 85 80 75
900 850 800 750 700 650 600 550 500 450
1900 1830 1730 1640 1580 1520 1460 1420 1360 1275 1150 1076 1004 894
94 93 92 91 90 89 88 87 86 85
375 350 325 300 275 250 225 200 175 150
3 6 9 12 15 18 21

FIG. 6.

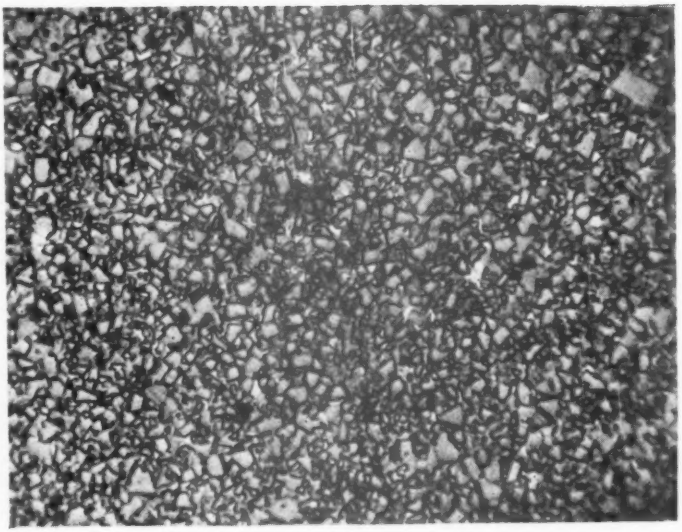


FIG. 7.

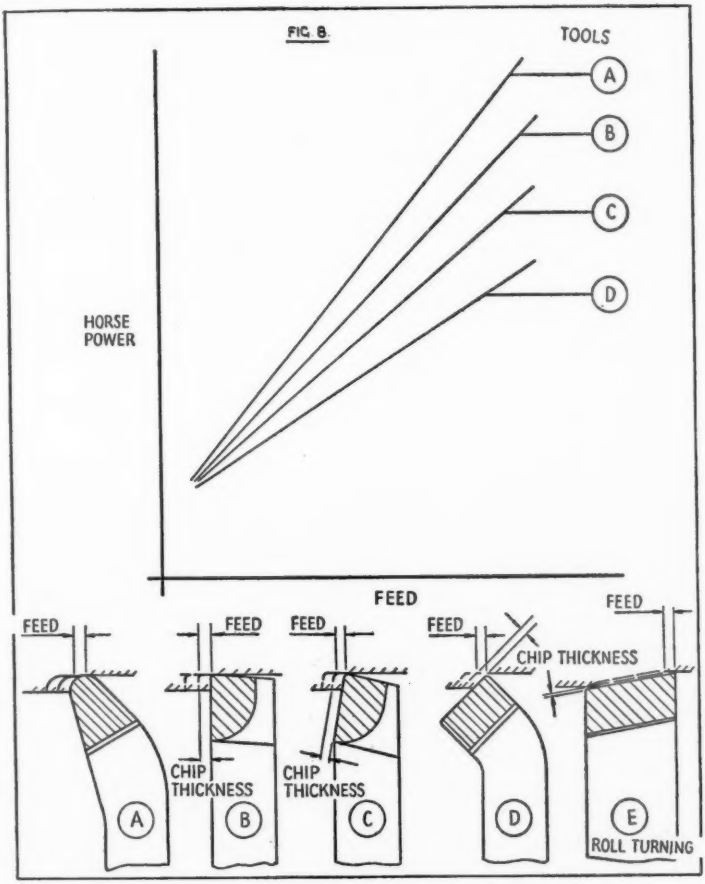


FIG. 8.
TOOLS
A
B
C
D
HORSE POWER
FEED
FEED
FEED
FEED
FEED
FEED
CHIP THICKNESS
CHIP THICKNESS
CHIP THICKNESS
A
B
C
D
E
ROLL TURNING

FIG. 8.

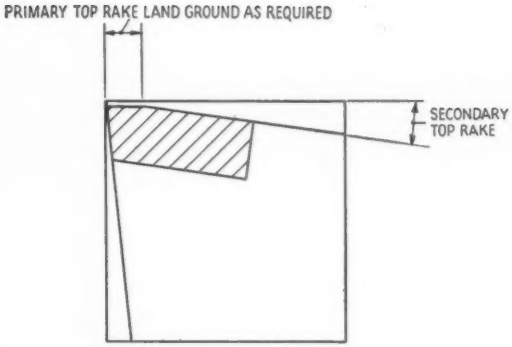

PRIMARY TOP RAKE LAND GROUND AS REQUIRED
SECONDARY
TOP RAKE

FIG. 9.

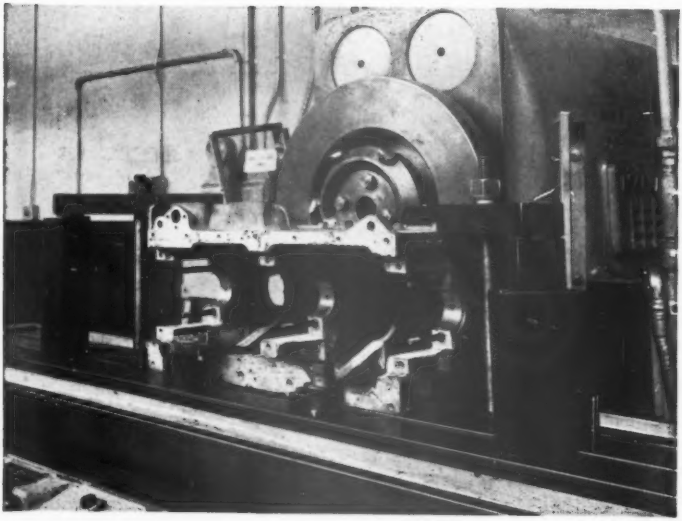


FIG. 10.

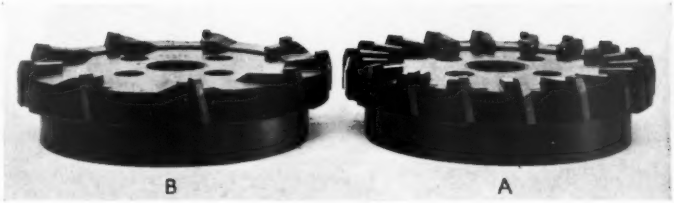


FIG. 11.

FIG. 12.

FIG. 13.

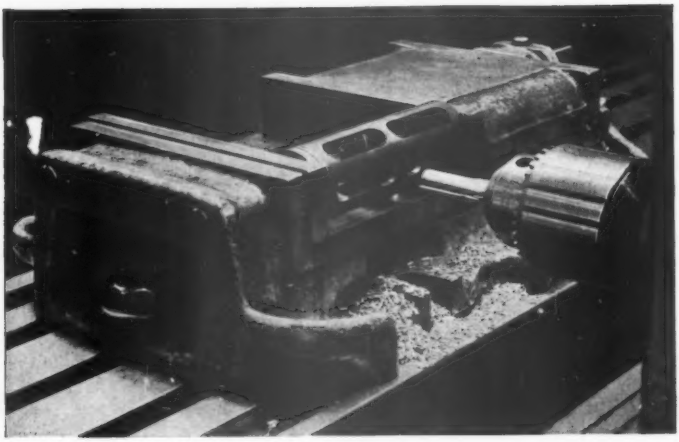
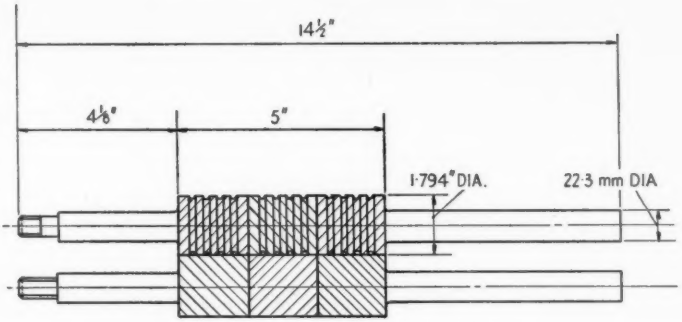


FIG. 14.



ONE PAIR OF WIMET ROLLS FOR ½" ROUNDS

FIG. 15.

FIG. 16.

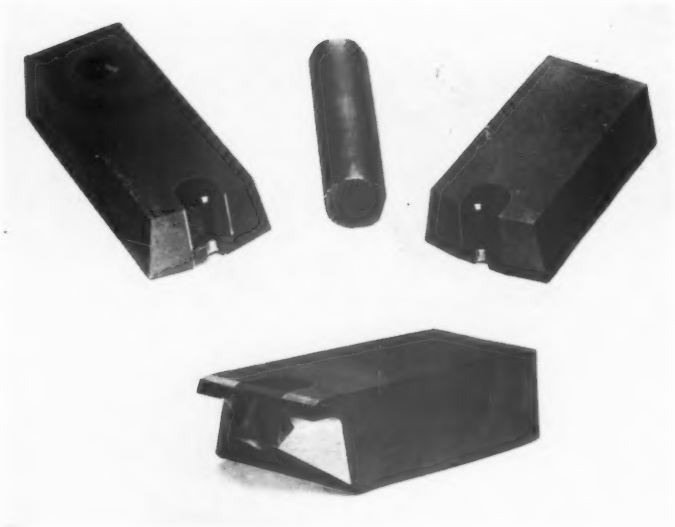


FIG. 17.

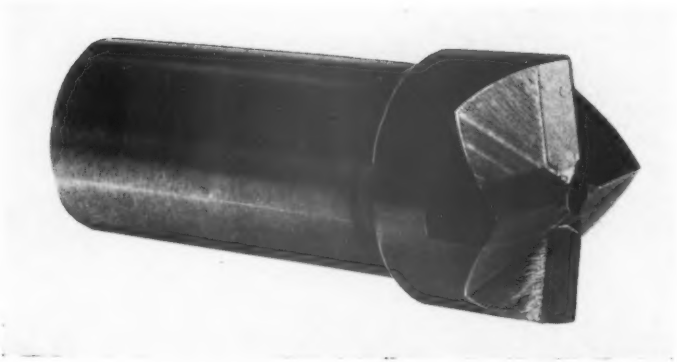


FIG. 19.

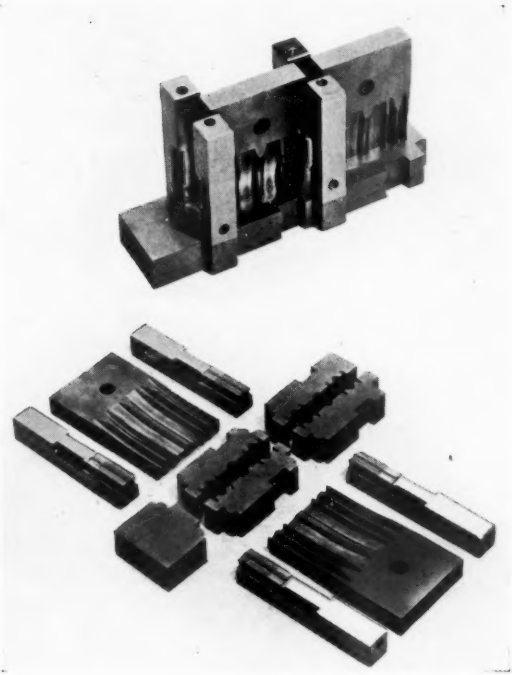
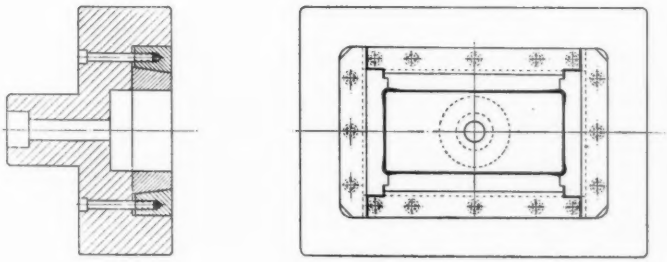


FIG. 18.

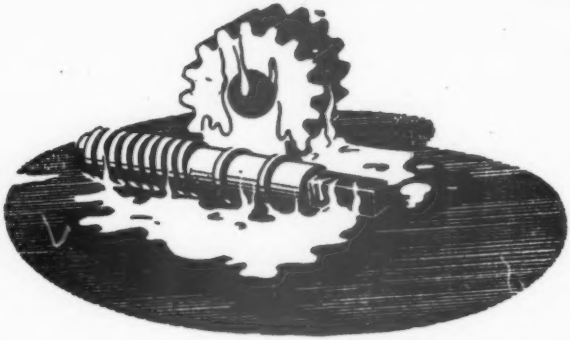


DRAWING TOOL WITH SEGMENTAL WIMET DIE

FIG. 20.

Notes

Notes



The Removal of Cutting Oil

In the fabrication of many components, cutting oil must be completely removed at various stages of production to permit the next operation to be carried out on a perfectly oil-free surface.

The usage of SOLVEX is deservedly popular for this work as even heavy-bodied sulphurised cutting oils, noted for their tenacity, are freed from intricately formed parts in a mere 5/7 minutes.

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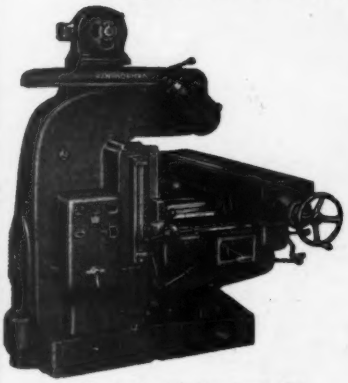

As a Vertical with Head set 45°

The rugged cutter head on these machines is adjustable to any angle between vertical and horizontal : it is mounted on a ram which has 19" of adjustment.

These features make it possible to do all the milling, drilling, boring, slotting, etc. on a component usually with **one set up.**

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Rapid traverse in both directions of table, also controlled front and rear

Made in nine table sizes $6\frac{3}{8}" \times 24\frac{1}{2}"$ to $13" \times 58"$

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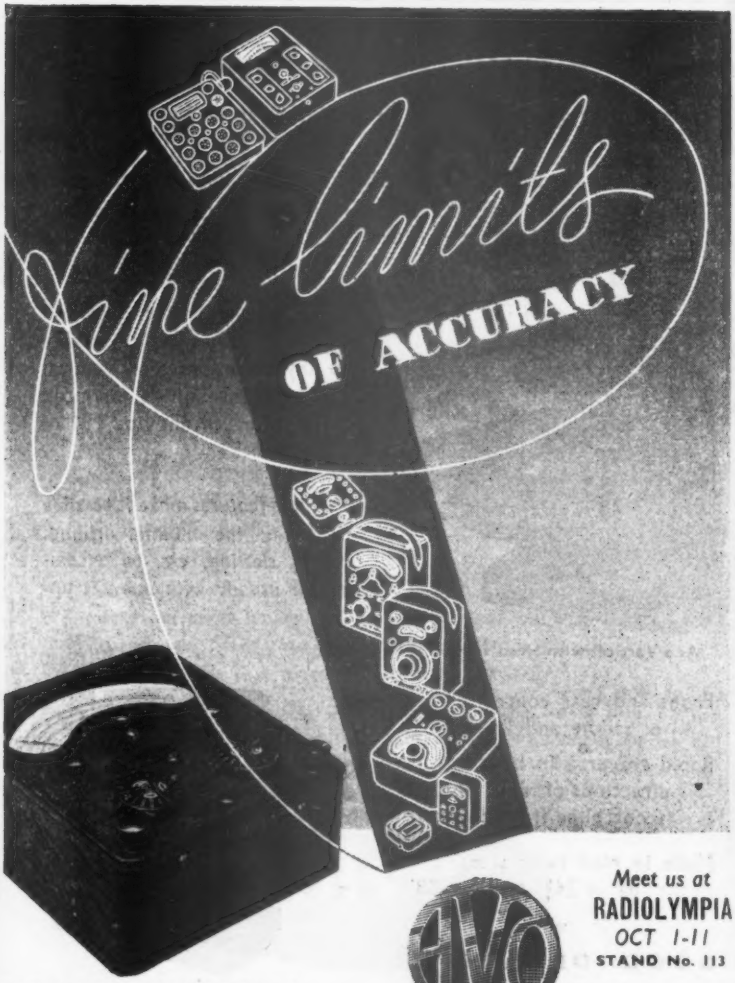

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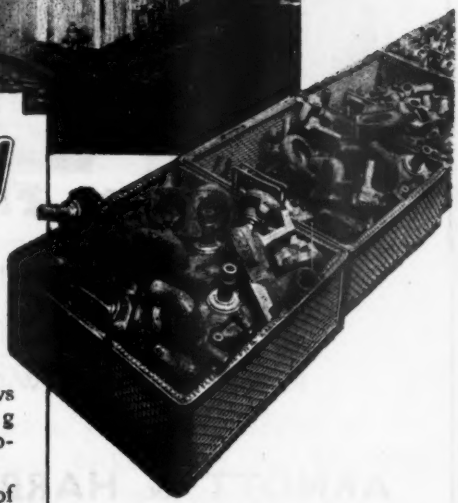

Bratby

INDUSTRIAL CLEANING MACHINES

This illustration shows a machine cleaning crank cases in the production line.

It is equally capable of cleaning small parts in baskets.

Photographs by courtesy of "Machinery.

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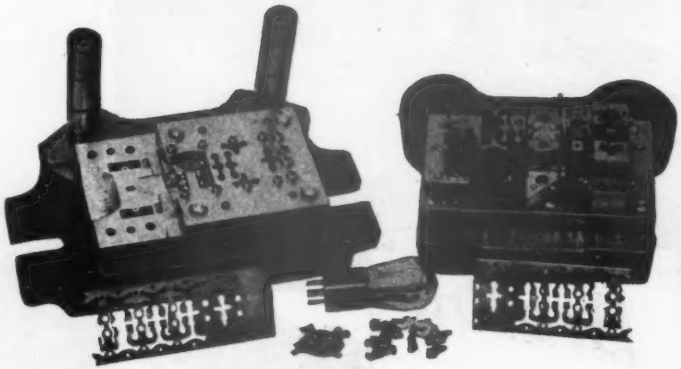

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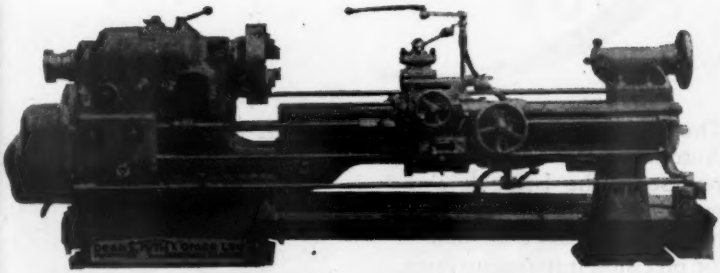

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Like all DSG Lathes, you can be assured of Service and Satisfaction, backed with over 80 years high class Machine Tool experience.

If the Machine you are looking for is not illustrated, we shall be pleased to send catalogues and particulars according to your requirements.

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The Barber-Colman Type "S" Automatic Hobbing Machine represents the latest development in high-speed, continuous hobbing of gears and pinions for precision instruments, such as clocks, watches, cameras, meters, etc., which require smooth, accurate gearing. It handles work up to 1 in. dia. by ½in. face in any machinable material. The machine is entirely automatic and is positively controlled by adjustable cams. The machining cycle consists of loading and clamping; rapid approach to the hob; feed; quick return; ejection and repeat. After set-up the operator can work several machines, it being only necessary to keep the magazine filled with blanks.

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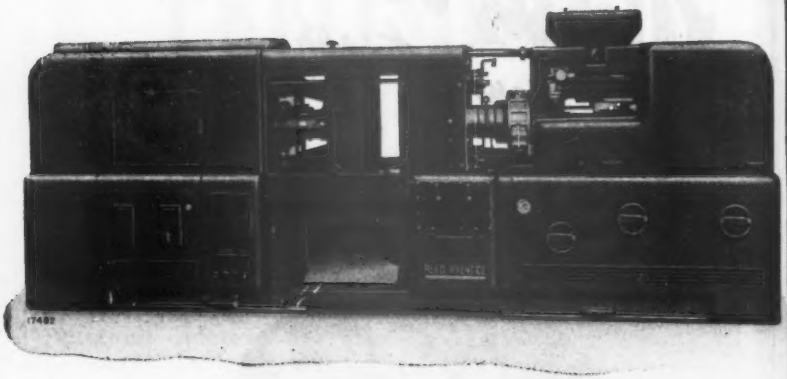

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"I regret, Mr. Might, that I cannot be equally effusive. I rate men like you no higher than grub-screws. It could be little pleasure to me even were you worth meeting, which you are not."

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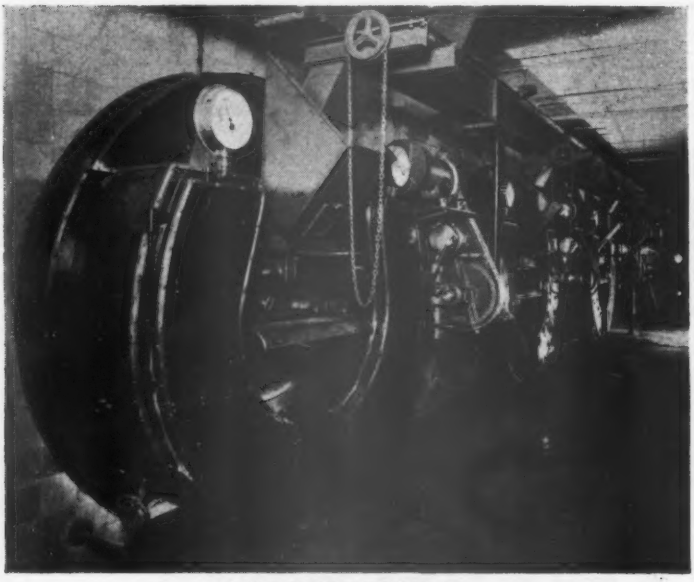

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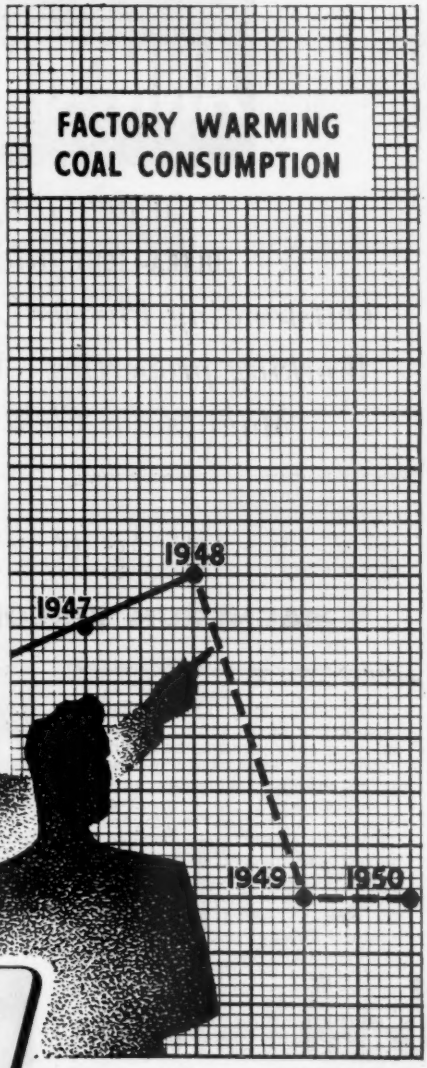

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Outstanding Physical, Mechanical and Working properties—Manufactured by Magnesium Elektron Limited

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We have long known that the addition of Zirconium to Magnesium alloys greatly reduces the grain-size, resulting in substantial improvement in mechanical properties including "workability." As a result of research, Elektron Magnesium-Zirconium Alloys have now been perfected and are available to industry.

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By courtesy of the De Havilland Aircraft Co., Ltd. Front casing for a De Havilland jet propulsion unit (Goblin I). Casting by Sterling Metals Ltd.

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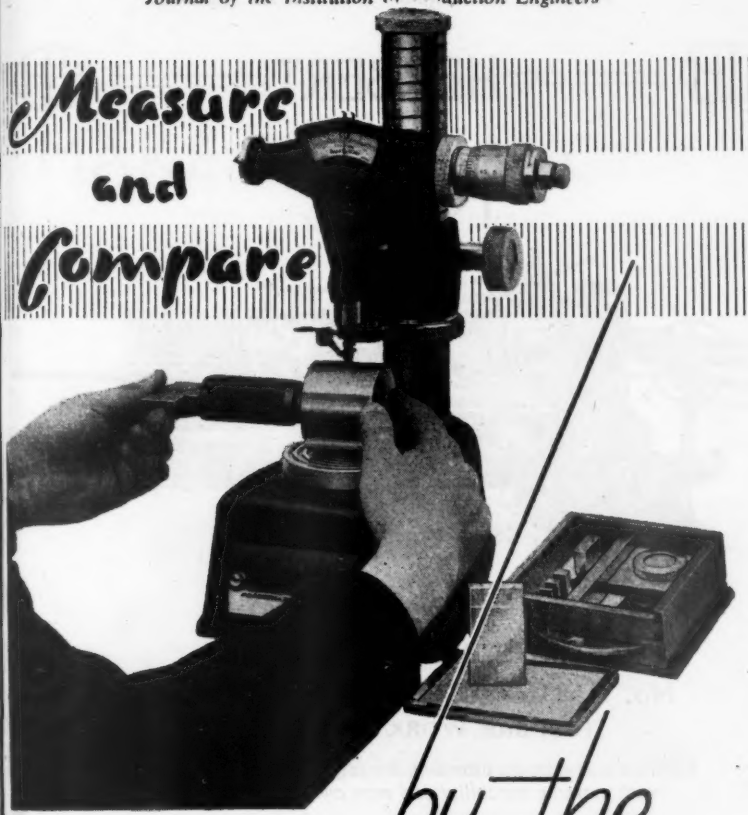

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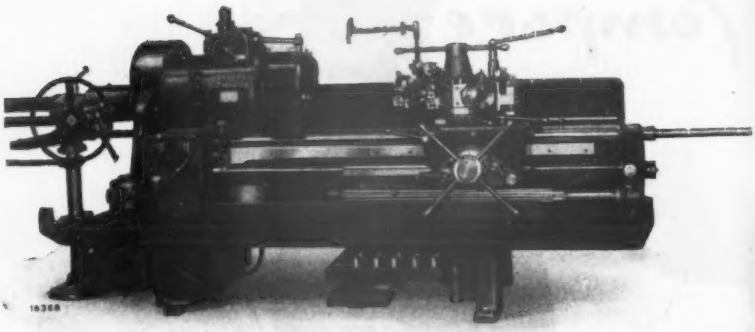

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SPEEDS UP TO 1520 R.P.M. for carbide tools
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MAXIMATIC

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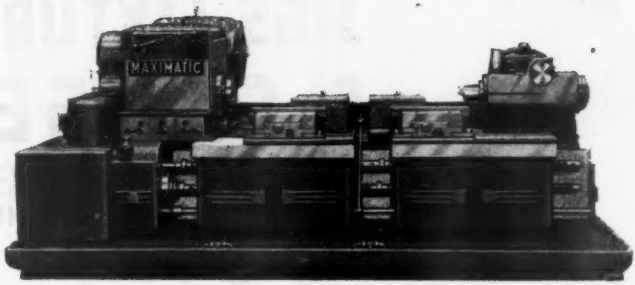

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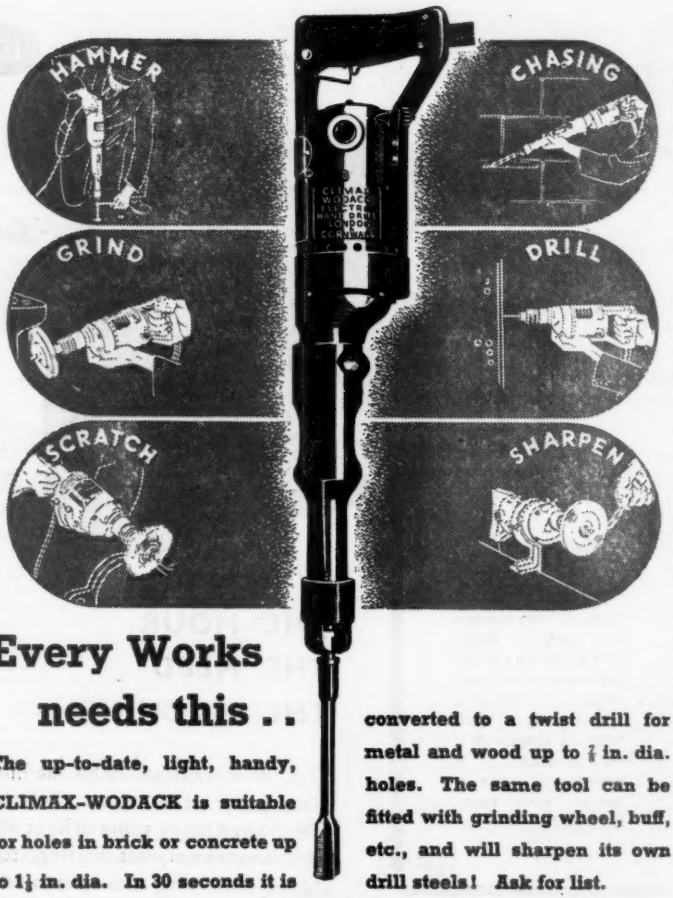

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No. 2 Capstan Lathe. Bar Capacity up to 1" diameter.

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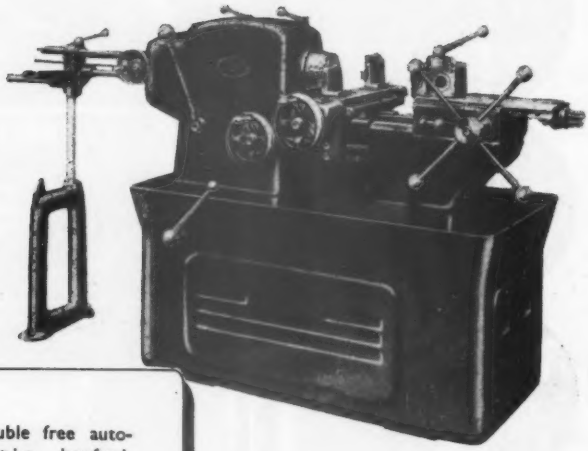

Trouble free automatic bar-feed. Pneumatic or hand locking for collets and chucks. Rapid interchange between bar and chuck work. Choice of 3 speed ranges, each with 12 speeds (6 if no gearbox). 6 power-feed rates to turret with same feed-shaft speed.

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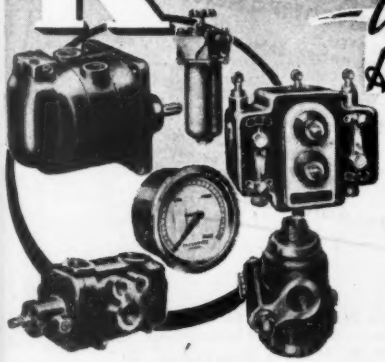

We are prepared to maintain and guarantee the efficiency of Keelavite plant in all cases where we are invested with the responsibility for the complete system, i.e., Pump, Motor (where this is used), Control Valves, Piping, Gauges, etc. The principle has possibilities for application to a wide variety of machines and if properly planned provides a control and flexibility superior to any other method.

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MOTOR (where required).

SPEED CONTROLS. Control Gear of conventional type for light, reasonably constant load, or a "Flow Control" System for heavy loads and where speed and load are subject to wide variations—this maintains appropriate speed whatever the changes in load.

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A TYPICAL APPLICATION FOR KEELAVITE POWER TRANSMISSIONS

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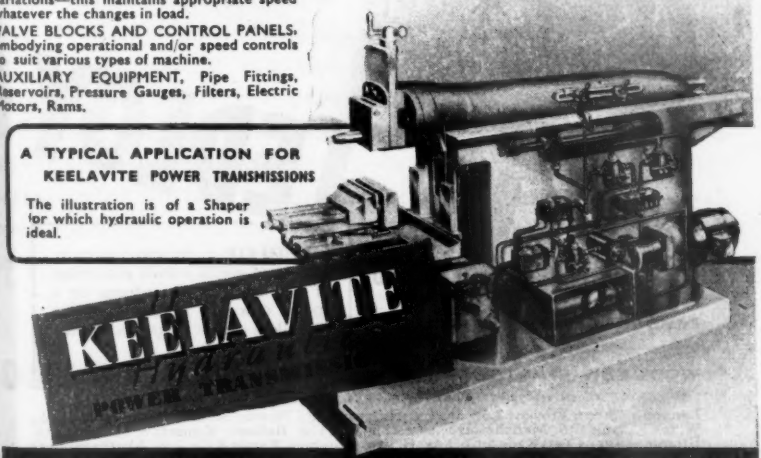

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CASE No. 4

CYCLE BACK-HUB COMPONENT

MATERIAL — FREECUTTING STEEL
MACHINES — SPECIAL PURPOSE SEMI-AUTOS
(all turning performed on a pair of machines)

ORDINARY CUTTING	LEDLOY FREECUTTING
Spindle Speed—395 r.p.m.	Spindle Speed—395 r.p.m.
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Floor to floor time—63 secs.	Floor to floor time—42 secs.
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VB.18 VERTICAL SURFACE GRINDER

FOR THE RAPID PRODUCTION
OF FLAT SURFACES

RANGE OF SIZES:
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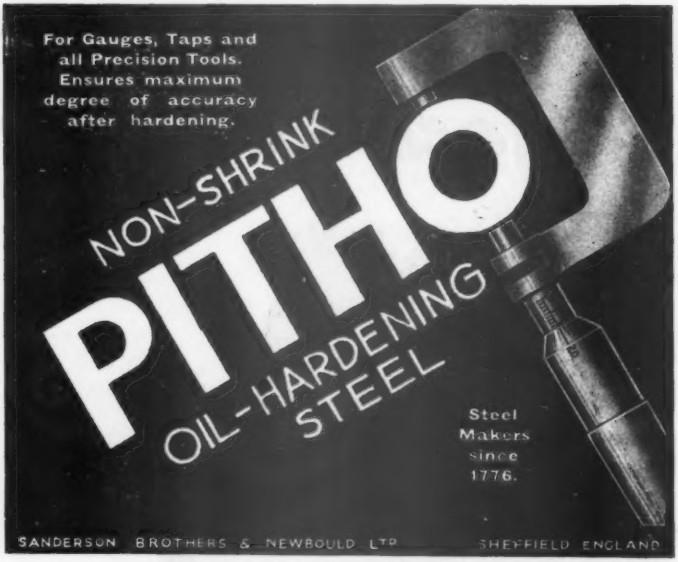
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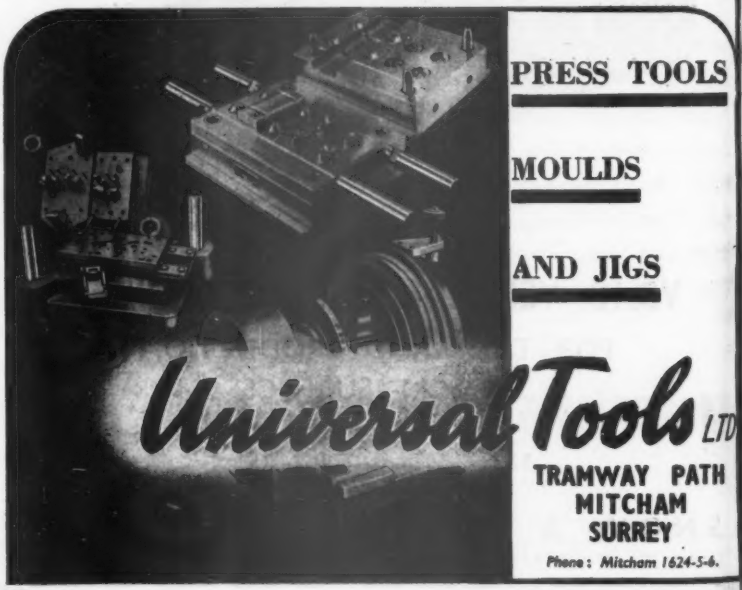
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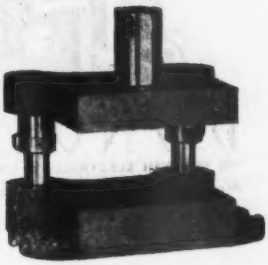

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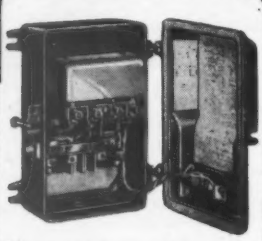

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ABRASIVE *n. Substance used for abrading—e.g., grinding, polishing, etc.*

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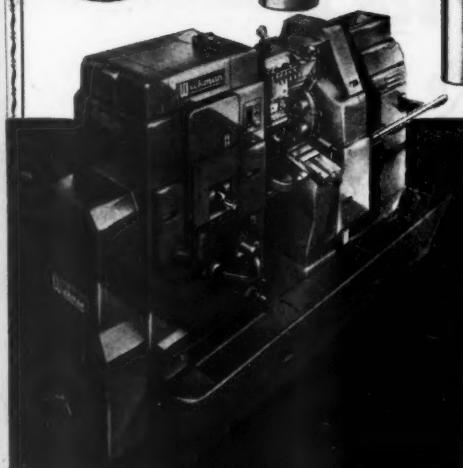

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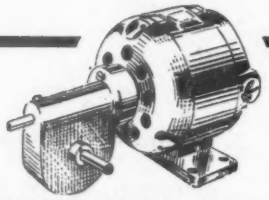

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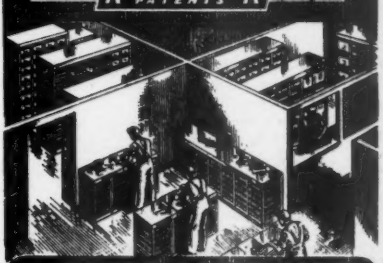

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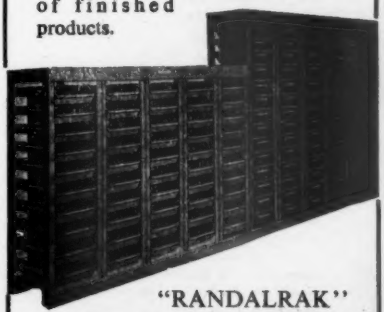

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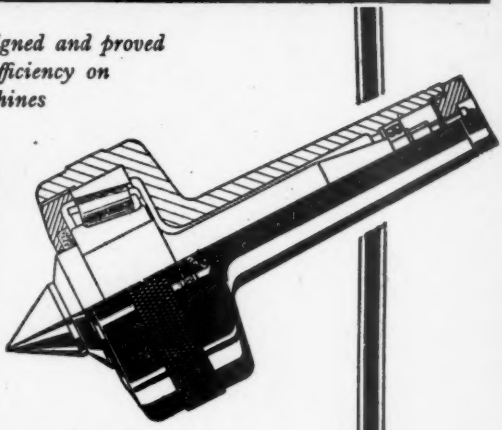
Here are two centres designed and proved by tests to give greater efficiency on modern Production Machines



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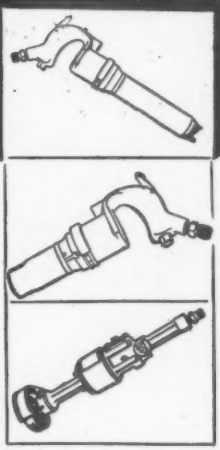

Joe has a pal who is a riveter. Bill does a man's-size job closing 1⅛ in. rivets. But he says that the new tool allocated to him is dandy for the job. It is a Holman "ER" Riveting Hammer, one of the new heavy duty tools. Hidden in a corner of the pneumatic tool store is a Holman "X" Hammer. Bill looks upon that as his own private property and he keeps it "cribbed up" against the time when he is running ⅞ in. rivets again.

Holman

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The first name for lasting service

HOLMAN BROS LTD · CAMBORNE · ENGLAND

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